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ABSTRACT

This six-chapter document (part of a series on biology and human welfare) focuses on agriculture and the teaching of this subject area. Major topic areas considered in the first five chapters are: (1) the development of agriculture; (2) agricosystems (considering agriculture as an ecosystem, land utilization and soils, soils and food production, irrigation, and others); (3) agricultural development and food production (examining agriculture and economics, crop zones, agrochemicals, and others); (4) biotechnology and agriculture (considering plant tissue culture, biofertilizers, animal husbandry, and others); and (5) agriculture, people, and food (discussing malnutrition, protein foods, future prospects, and others). The sixth chapter is a curriculum guide for teaching about agriculture in biology courses. Comments on how the subject fits into secondary school biology courses, descriptions of various teaching and learning strategies, and a chart on agricultural aspects of biological education (listing areas of concern and concepts, principles, and/or topics with related practical experiences, teaching/learning strategies, and values/skills fostered) are included. A list of references and resources is also included. (JN)

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The Beginning of Agriculture

The phylogeny of the human species extends back some 3.5 million years, the remains of African man, *Australopithecus africanus*, giving supporting evidence of this. The ancestors of man, *Homo sapiens*, emerged sometime between 100,000 and 200,000 years ago. It has been suggested that man began practising agriculture some 10-20,000 years ago. There is evidence to show that wheat, barley, millet and lentils, in particular, were cultivated about 10,000 years ago. It is said that agricultural practice started with the discovery that seeds could be used to grow new plants, and developed with the selection of particular types of plants and later animals from wild stocks. Anthropologists have written extensively concerning the development of early man and his food gathering habits. The centres of origin of agricultural practice seem to have been the fertile valleys of the Tigris, Euphrates and Nile, and, somewhat later, that of the Amazon. Not only was the selection of food plants and domestic animals important in the emergence of agriculture, so also was the development of tools and of forms of social organisation, such as the development of settlements.

It is interesting to note that different food crops were domesticated in different parts of the world: wheat and barley in S.W. Asia; rice and bananas in S.E. Asia; sorghum and millet in East Africa; and maize and potatoes in South and Central America, while domesticated animals come largely from Asia (Fig. 1).

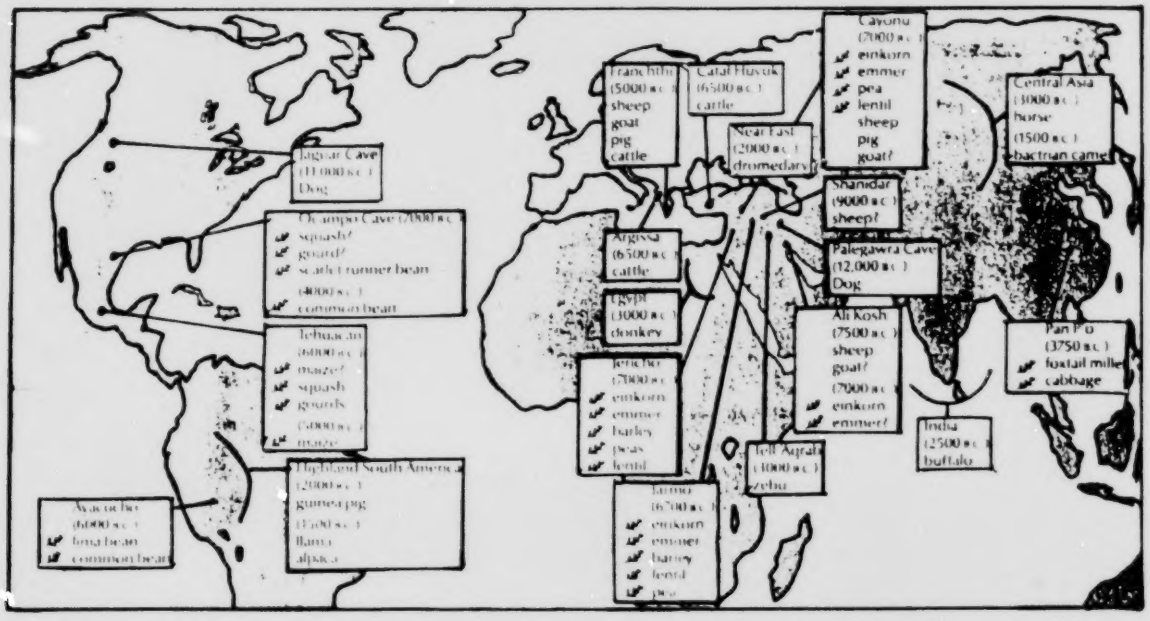


Fig. 1. There were many early centres for the domestication of plants and animals. The Middle East has yielded much information, partially as a result of the relative ease and long period of exploration and the dry climate favouring preservation of artifacts. The Middle East is also the location of the oldest sites to date. Missing from this map are sites for domestication of tropical root crops; far less is known about tropical root crops than about crops from more temperate zones.

Agriculture developed as man changed from hunting animals for food to raising and herding animals, initially for food and then, also, to help with transport and labour (e.g. horses, buffalo) and to provide clothing (e.g. sheep and goats). The clearance of ground, the growing and harvesting of crops, together with the droppings, trampling and grazing effects of herds of animals, must have had an effect on existing vegetation and soils, bringing about, over time, significant changes in landscapes. Evidence suggests, for example, that the keeping of domesticated goats and sheep has been responsible for the clearing of forests and soil erosion in some parts of the world. The domestication of a limited number of species of animals (e.g. cattle, chicken, dog, goat, horse, pig, sheep, water buffalo) and plants (e.g. banana, barley, beans, cassava, corn, coconut, potato, rice, sugar cane, sorghum, wheat, yam) changed man's position from that of a food gatherer to one of a food producer, changing man's relationships with biological communities. The effects on man of the development of agriculture were sufficiently dramatic as to be described as revolutionary. The greater certainty of food availability, through production and storage techniques, enabled human populations to increase and provided the potential for later urban development. (Fig.2)

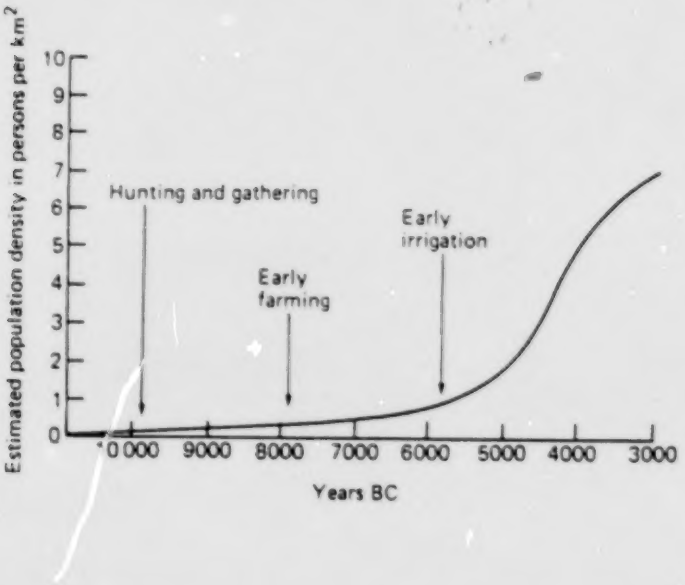


Fig. 2. Increase in population density in Iran during the transition to agriculture.

Modern Agriculture

The development of modern agriculture has its roots in the European Renaissance of the 16th and 17th centuries. The voyages of the European explorers initiated a considerable exchange of crops

and domesticated animals between continents. To-day, one finds production centres of many important economic crops located far from each plant's original home (Fig. 3).

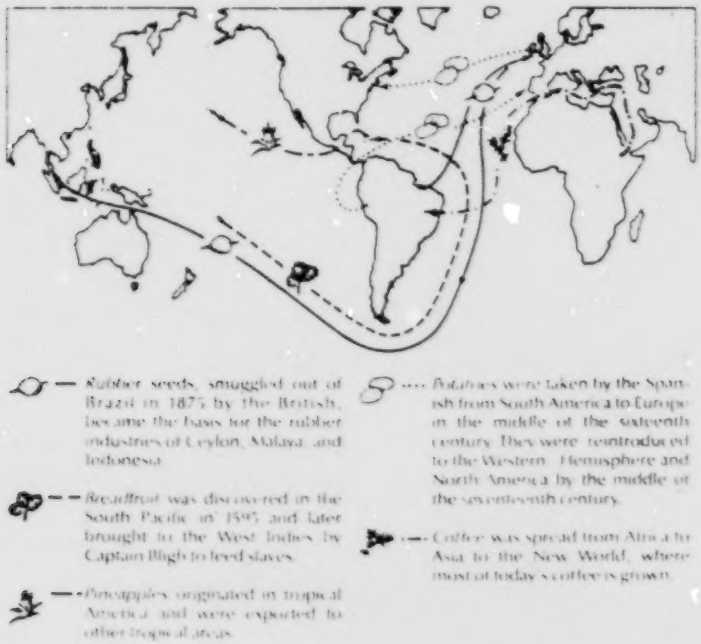

Rubber seeds, smuggled out of Brazil in 1875 by the British, became the basis for the rubber industries of Ceylon, Malaya and Indonesia.
Breadfruit was discovered in the South Pacific in 1595 and later brought to the West Indies by Captain Bligh to feed slaves.
Pineapples originated in tropical America and were exported to other tropical areas.
Potatoes were taken by the Spanish from South America to Europe in the middle of the sixteenth century. They were introduced to the Western Hemisphere and North America by the middle of the seventeenth century.
Coffee was spread from Africa to Asia to the New World, where most of today's coffee is grown.

Fig. 3.

Agricultural practice in Europe in the 18th and 19th centuries was marked by a more systematic approach to, for example, crop and livestock improvement, rotation, drainage and irrigation, paralleled by the emergence and use of new machinery as a result of developing technology and industrialisation. It is difficult to disentangle the interplay between science and technology; for example, the breeding techniques leading to livestock improvement and plant hybridisation practised in 19th century Europe provided a foundation for the development of the science of genetics, subsequently the discovery of the principles of heredity have provided a basis for more systematic breeding techniques. It is, however, true to say that the emergence of modern science in the 17th century has paralleled the development of modern agriculture and that scientific techniques and knowledge have become increasingly applied to agricultural practice.

A feature that has characterised the development of agriculture in modern time has been that increased mechanisation has led to a reduction in manpower needs. It has been estimated that in the beginning of the 16th century about two-thirds of all people were engaged in food production; to-day, it is on average one person in five, with a much lower figure for industrialised countries. The

migration of peoples, in the 19th and to some extent 20th centuries, particularly from Europe, to, for instance, the Americas, Australasia and parts of Africa, taking with them their techniques, livestock and crops, increased cultivated land and disseminated techniques. The emergence within this century of international organisations such as FAO, has been a further influence in the dissemination of techniques and promotion of particular practices that have been influential in moulding the character of modern agriculture world wide.

To-day, one can still see examples of most of the types of agriculture that have been invented by man, from the least intensive form of shifting agriculture to the higher productivity forms of crop rotation and multiple cropping. In some parts of the world, land holdings are small, agricultural practice is labour intensive and based on traditional practices, often many hundreds of years old, productivity is low and markets served are very local. In contrast to this are areas where land holdings are larger, sometimes very large, agriculture is highly mechanised with low manpower needs but very high energy needs, cropping is intensive and productivity very high. Such farming uses modern methods of storage and transportation and so is able to exploit large markets, often world markets. The aims of such agriculture are usually to maximise production per unit of land area; to reduce to the minimum annual or seasonal fluctuations in productivity and to prevent long-term degradation of land. Success in achieving such aims is inevitably affected by factors such as climate, soil, technology, food preferences, social customs of peoples and their political and economic priorities. In pursuit of these aims, research and development over a wide area have been promoted and the results applied to farming practice. Consequently, the maintenance of the productivity of much of modern agriculture is dependent upon the continuing activity of pure and applied scientific research.

CHAPTER 2

Agroecosystems

Agriculture as an Ecosystem

An ecosystem is a unit of study which attempts to describe the dynamic situation in which groups of individuals live in a community in a particular physical environment. In an ecosystem, there are many interactions between the various elements of the community and with those of the physical environment (air, water and minerals of the earth's crust). Natural ecosystems have developed over time from simple communities to more complex ones in which there are larger numbers of different kinds of organisms. Mature ecosystems are the most stable in that they are the least liable to great fluctuations in number of individuals of a particular species from year to year. Tropical rain forests and coral reefs are examples of complex mature ecosystems.

Any ecosystem develops by the growth and activity of particular groups of plants and animals on a suitable piece of land or in water. The plants build up complex substances through photosynthesis, using simple inorganic compounds and solar energy. Thus, green plants are the major producers in a community and all other organisms depend on them for their food. Autotrophs (photosynthesising plants) provide food for hetertrophic organisms, which can themselves be classified as consumers (e.g. animals) and decomposers (e.g. bacteria and fungi). The feeding relationships within an ecosystem can be described as food chains. However, feeding relationships are often complex, herbivores may feed off a variety of plants, carnivores may feed off more than one animal, e.g. an owl may eat mice, snakes or lizards; such complex feeding relationships are best described as food webs. At each level in a food network, energy and materials will be used up, so that there is less available for the next level of the network. The structure of the energy levels of the feeding relationships within a community are usually depicted diagrammatically as a pyramid of biomass (Fig. 4).

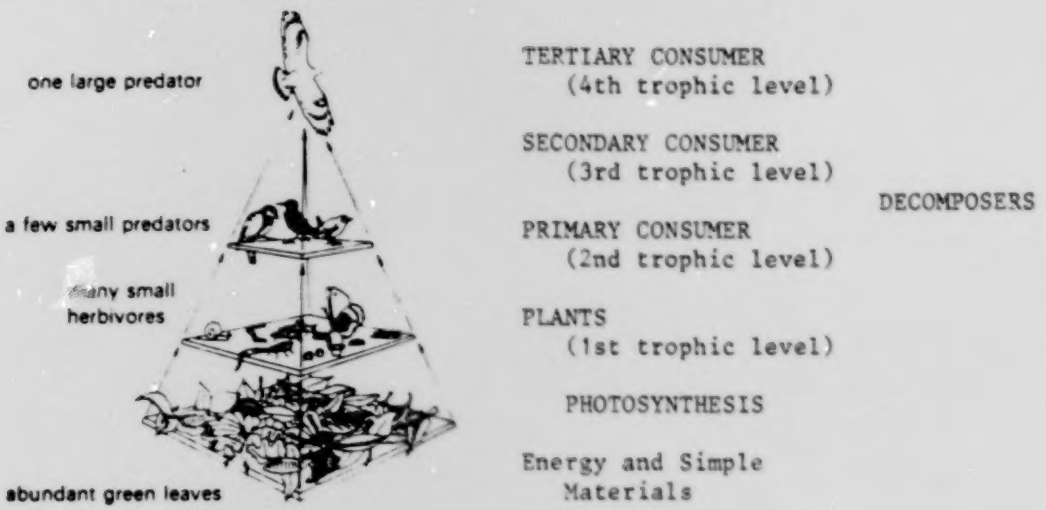


Fig. 4.

Man is a major consumer within an ecosystem, depending on various animals and plants for food. With the development of agriculture, we can look upon man's actions as efforts to simplify the biological relationships within an ecosystem to his own advantage. An agricultural system attempts to reduce the elements in man's food web to a simple producer-consumer relationship, with also the decomposer system greatly modified as plant growth is maintained by adding fertilisers to the soil. Thus, an agricultural system is a greatly simplified ecosystem, with man attempting to maintain its stability through the use of fertilisers, pesticides, irrigation, etc.

Land Utilisation and Soils

It is estimated that only one-third of the world's surface is occupied by land and that of this it is not possible to cultivate one-fifth due to a variety of reasons, such as, for instance, unsuitable terrain and soil conditions (Fig. 5). About 110 million square km of land area is biologically productive, supporting (a) temperate and tropical forests (28 million sq km); (b) managed forests, small woods, and grassland (65 million sq km); and (c) agricultural land (17 million sq km). There is a constant conversion of forest land to other uses, such as human habitation, agriculture and recreation. The size of the forests is shrinking rapidly in both the developed and developing world. The pressure on cultivated land is also increasing; it has been estimated that during the period 1970 to 1980 about 12,000 sq km of agricultural land was lost due to urbanisation.

In order to provide a more rational basis for effective long-term land use planning, a balanced ecosystem theory has been put forward. This stresses the importance of maintaining balance of both young and mature ecosystems in the world. A young ecosystem is characterised by production, growth and increased quantity of biomass, while a mature ecosystem maintains fairly constant levels of production, growth and biomass and so stabilises soil and water resources without external intervention. The increased production associated with the young ecosystem supports the growth and accumulation of biomass on the land surface, whether it be agriculture or forestry. Natural forests and grasslands are examples of mature ecosystems; clearing such areas produces young ecosystems. The products of man made young ecosystems, whether forest or agriculture, are usually removed for use by man and this affects the quality of the soil.

Soil plays a most important role in agriculture and certain types of soils are suited for certain kinds of crops. When forests or grasslands are cleared to prepare the soil for crop cultivation, the surface soil - usually called 'top soil' - is directly exposed to weather conditions. The top soil consists of humus, rich in organic contents, usually darker in colour than the sub soil, which is hard, rocky and of variable colours. The humus supports plant growth to a very large extent. Good aerated soil, with some organic content, is best suited for growing many types of crop plants.

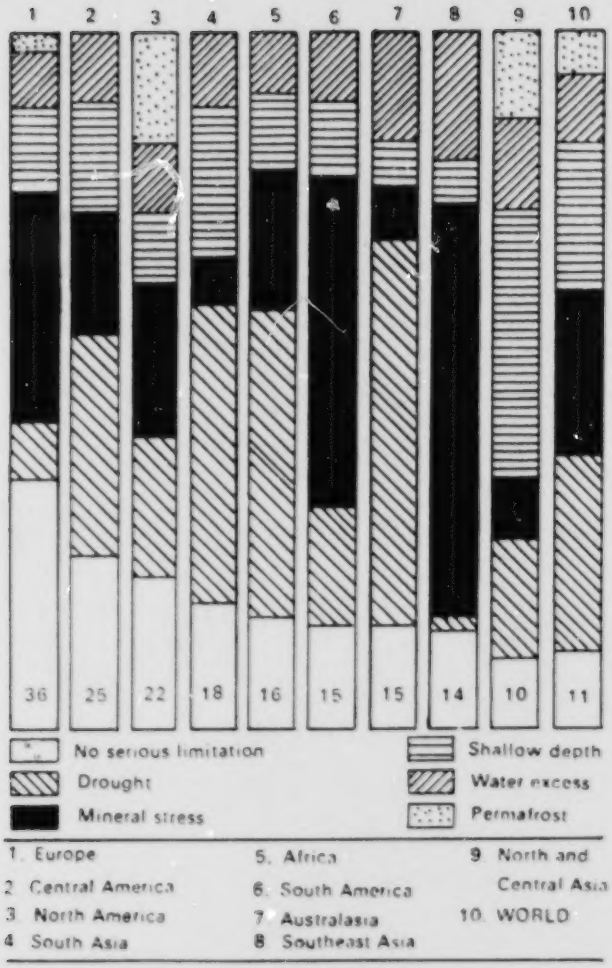


Fig. 5. Regional distribution of soils with or without limitations for agriculture. Source: Allen (1980).

The water passes through the aerated soil and helps the dissolution of the organic matter, providing the nutrients absorbed by the plants. The inorganic nutrients in soil vary depending upon the parent rock material. The organic part is from the decaying plant and animal remains decomposed by fungi, bacteria and other micro-organisms. The primary sources of organic matter are the forests or grasslands and the removal of these impairs the recycling mechanism of humus and minerals in nature and the soil can become poor with little or no nutrients to support plant growth. Cultivation of crops year after year on the same soil does not help mineral enrichment since most, if not all the plant parts are removed from the field, very little organic matter is left behind; hence, usage of fertiliser

is a necessity. Over exposure of soil for long periods of time is not desirable, since the soil becomes very loose and soil particles are blown away easily by wind and heavy rains cause the leaching of nutrients, which in turn impoverishes the soil. Many of the present day deserts were once suitable for agriculture but over-grazing and removal of the top soil has made these lands unsuitable for cultivation.

Soils and Food Production

It is estimated that most countries in the developing world will be unable to produce food yields at even the minimum subsistance level to feed their expected populations by the year 2000 AD.

The Food and Agriculture Organisation (FAO) has recently completed a ten year survey on the quality of cultivable land and possible increase in agricultural output in 117 countries. Most of these are developing countries in Asia, Africa and South America. Climate maps and soil maps were prepared and superimposed in order to calculate the potential yield of at least one major crop commonly grown in the area under study. The length of the growing period of the crop was also taken into account. The data obtained was helpful in determining the countries that could support their increasing population by the year 2000 and to distinguish them from those which could hardly manage and those that would be in very critical condition. Three levels of production were taken into consideration with reference to the agricultural inputs :

(a) Low level input. Traditional methods of cultivation, using no fertiliser or chemicals, no conservation measures, depending on traditional seed sources as seen in some of the least developed countries, especially in Africa.

(b) Intermediate level input. Cultivation methods modified or improved with productive crop mix, usage of fertilisers and chemicals, using improved seed varieties, conservation measures, as seen in some of the middle and small commercial farms in Asia and Latin America.

(c) High level input. Modern agronomic practices, high usage of fertilisers and chemicals, using improved varieties of seeds, conservation practices very common, mixing up of crops for high level production, as seen in developed countries.

It was predicted that methods involving low level inputs could produce in the African countries sampled enough food to feed 1.5 times the expected population in the year 2000 AD, 1.4 times in the countries of Central America and the Caribbean and 1.1 in the Asian countries sampled. The prediction for the Middle East countries was that they

would be deficient in food by the year 2000. If agricultural production were to be raised, using methods involving high level inputs, then it was suggested that the Asian countries could produce enough food to feed 3.3 times the expected populations in the year 2000 AD, the Central American countries 6 times, the African countries about 16 times, and in South America about 32 times their respective expected populations in the year 2000 AD.

In this forecast, it is assumed that there would be free movement of food across the borders of different countries and that people would have enough money to buy food. When the 117 countries are classified according to the use of low level input methods, 65 countries, with a population of 1,065 million, are expected to be able to feed their future populations. These 65 are considered as critical countries and 30 of them (out of 51) are in Africa, 15 (out of 16) in S.W. Asia, 6 (out of 16) in the rest of Asia, 14 (out of 21) in Central America and the Caribbean. The 13 South American countries are expected to be above the critical level. If the input level is raised to an intermediate one, the situation in 29 of these 65 countries would no longer be expected to become critical and, with the use of high level input methods, another 17 countries would be expected to reach self-sufficient levels of production. The situation in the remaining 19 countries, including 12 in the Middle East (with a total population of 104 million) would still be expected to remain critical, even if high level input methods were attempted. Much of the land has soils which are severely limited and generally unsuited for cultivation. The potential for higher agricultural production is thus very unevenly distributed among the countries of the developing world. In several cases, such as in East Africa, for example, some of the countries in very critical conditions are next to countries with high agricultural production and the possibilities for resolving some of the problems of feeding their rising populations exist.

The overall outlook on the food situation world-wide in the coming decade is not very hopeful, unless certain major advances are made in areas such as agronomy, plant genetics and food storage. In addition, the use of land resources also needs to be improved alongside improved controls of human populations.

Any modified ecosystem, such as agricultural land, consists of plant organisms, inanimate constituents of nature and man-made components. Exchange of energy and materials with one another and the environment is common. Each constituent part in this exchange will have its own sub-group or units and each unit functions in its own way but all of them maintain an equilibrium. Agricultural ecosystems function in relation to natural or semi-natural environments created by man and should be examined in relation to the cultivated landscape, exchange of energy and matter between the systems. In mature agricultural lands, the exchange of energy and matter is always stabilised, matched or balanced with one another. The process of stabilisation takes several decades before it settles down, when new lands are brought under cultivation. In case of

flat or levelled agricultural land, this stability is reached at an early period, whereas with land involving steep gradients or mountain slopes, there is an undirectional flow of materials from the land. Unless the ground is well protected with a proper cover, the annual material and water loss can be very heavy. Water, soil and mineral depletion is common in such agricultural lands. The slopes are depleted year after year and the washed out materials settle down on the flat grounds or plains. The soil fertility variation becomes very wide between the slopes and the flat ground below. Eventually, the slopes may be completely depleted of their mineral or organic content and the land becomes totally unfit for cultivation. Big landslides and loss of top soil become a common feature at frequent intervals, especially during rainy seasons. The terrace cultivation of tea, coffee or other highland plantations on hills are good examples of well developed cultivations, illustrating the prevention of soil erosion and fertility.

Flooding and silt deposition of big rivers pose other problems. While the soil fertility alongside such rivers is enriched after floods, the extent of damage caused by floods to the agricultural ecosystem will be enormous after each flood. Disturbances in, for example, the alkalinity and salinity of areas of intensive agriculture create major problems, since these imbalances in such ecosystems cause heavy damage both to the crops and the people (Tables 1 and 2). Such agricultural ecosystems need to be well protected by applying relevant scientific knowledge and principles. The watershed areas should be protected; major rivers and their tributaries need to be monitored to avoid any large-scale flooding. Development of hydro-electric projects, which is often encouraged in many developing countries, can be used to control flooding and develop irrigation which, together with electricity production, can be helpful in maintaining agricultural ecosystems.

The development of new agricultural land is a slow process. Crop production and raw materials resulting from such development vary considerably during the early period of farm land usage. Good management practices are essential to bring such land into a productive and stable agricultural ecosystem. When conditions are stabilised, neither the yield nor the soil fertility is reduced. This is exemplified by the fact that rye and wheat cultivation in Europe, and rice cultivation in East Asia, have been practised for hundreds of years without any serious decline in yield or soil fertility. Both more intensive use of existing cultivated land, together with the bringing of some new land into cultivation, are important elements in attempts to increase world food production. However, in order to avoid serious ecological disorders in the future, the former method should be tried to the maximum before pursuing the latter. Existing forests should, as far as possible, be maintained and soil conservation given very high priority in all attempts to increase food production.

Table 1. Extent of problems affecting rice lands of South and Southeast Asia.

Soil problem	Area (million ha)
Salinity	53.2
Alkalinity	7.0
Acid sulfate soil condition	5.3
Peat soil condition	21.0
TOTAL	86.5

Source: International Rice Research Institute, Los Baños, Philippines.

Table 2. Performance of rice varieties/lines tolerant of problem soils.

Soil problem	Variety or line	Yield (t/ha)
Salinity	IR50, IR5657-44	3.6
Alkalinity	IR36, IR4595-4	3.6
Strong acidity	IR42, IR4683-54	4.2
Peat	IR42, IR8192-31	3.1
Aluminum toxicity	IR43, IR6115-1	3.8
Phosphorus deficiency	IR52, IR8192-200	4.4
Zinc deficiency	IR36, IR8192-31	2.9
Iron deficiency	IR36, IR52	2.8

Source: IRRI (1981).

It should be possible, through the application of modern methods of agriculture, together with increased investment in agriculture, to improve food production levels. However, this cannot be achieved without the help of governments and some inter-governmental cooperation. Agricultural economics are inevitably part of wider economic and social structures.

Irrigation

Irrigation is absolutely essential in certain parts of the world and especially for particular crops but continuous and intensive irrigation, as well as occasional or frequent floods, can reduce soil fertility under certain conditions. Waterlogging and salinisation

are very common due to incorrect irrigation and swamp lands often result with many mineral deficiencies (Tables 1 and 2). Soil infertility leads to drop in yields.

Salinisation is primarily caused by the raising of soil water with dissolved salts on to the surface. When the surface water evaporates, so the salt concentration increases in the top soil layers. Cultivated plants in such soils show unusual responses. Water absorption by the plants becomes poor due to an increase in the osmotic pressure of the soil water and in turn this reduces plant growth. Nutritive disorders set in and the yield becomes poor. In those areas where the rainfall is limited, the accumulated salts on the soil surface or subsurface may not be washed off. Drains and ditches can be dug to remove the excess salt and these help to drain the subsoil salty water that affects the growth of plants. In dry regions, where irrigation is common, there needs to be also a good parallel drainage system to wash out the excess salts.

Most irrigation systems depend on rivers or canals. The drains and ditches also carry back the irrigated water to the natural flow sources, like rivers, and so naturally these join the river and there will be a higher salt content bringing about undesirable limnological changes, including the development of certain types of undesirable fauna and flora. Excessive irrigation can thus affect soil or water quality and effective remedial actions may become necessary to control water pollution.

It is well recognised that improved water resources and utilisation is an important factor that promotes food production. During the last two decades, many countries have spent vast amounts of money on managing their rivers and for building huge dams, irrigation channels, etc. The areas under irrigation have considerably increased in different continents and, as a consequence, the cultivated land area, yield and production have also increased (Table 3).

Table 3. Increase in areas under irrigation (million ha): 1961-1965 to 1977 (annual average)

	1961-1965	1977	Percent increase
Africa	5.8	7.8	13.4
Asia	100.0	128.8	28.8
South America	4.9	6.5	32.6
All developing countries	110.0	144.9	31.7
All developed countries	39.0	52.9	35.6
World	149.0	198.0	32.9

Source: Data taken from FAO.

Subsurface drip irrigation offers an effective and efficient method of water usage and conservation. This technique has been adopted in certain countries. In coarse texture soils frequent irrigation becomes necessary because of its high drainage and poor water-retaining capacity. The initial cost of establishing drip irrigation is, no doubt, high but the method is very effective compared with the water-well systems or irrigated fields. Furthermore, a considerable quantity of water can be saved using a drip system besides lower labour, energy and other costs.

Fertilisers

The use of a fallow period for the land, during which the soil recovers its fertility, has been gradually eliminated and replaced by the application of fertilisers. In the majority of developing countries, the fertilisers used are of an organic nature, mostly animal dung and other wastes. After the second world war, the use of inorganic fertilisers became very common in many parts of the world and now different kinds of fertilisers are manufactured, both for general use and for specific crop plants. A combination of nitrogen, phosphorus and potassium salts makes up the general or all-purpose fertilisers. More than 45 million tonnes of fertilisers are used annually in the world (see Fig. 5).

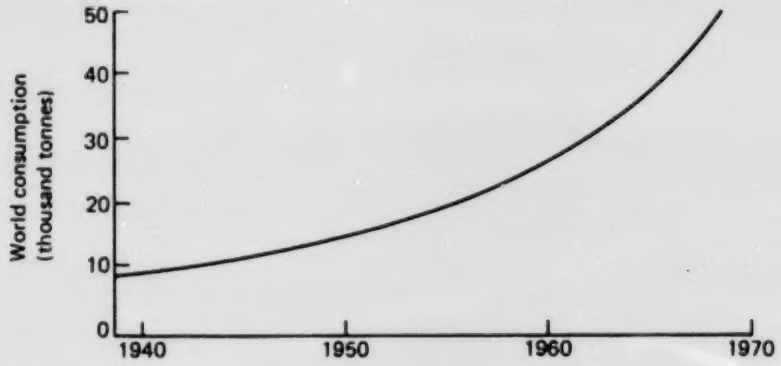


Fig. 5. World fertiliser consumption in thousand tonnes (excluding USSR and China).

An average of 4-12 kg of fertiliser is applied annually per hectare, depending whether the land is in a high or low rainfall area. Very little fertiliser is needed in dry areas, since the plants do not absorb the nutrients as water availability is limited. Inorganic fertilisers have disadvantages, particularly if used indiscriminately, the highly soluble nitrate (NO_3^-) is readily leached from the soil and can accumulate in underground water courses, eventually reaching rivers and lakes. This has two possible consequences: water with

high nitrate concentration (a) is unfit for human consumption, and (b) leads to an increase in the growth of aquatic algae, which are then decomposed by bacteria; this, in turn, leads to a depletion of the oxygen content of the water and so reduces fish and other oxygen consuming species. Undoubtedly, organic fertiliser is the safest to use but the quantity required is often far greater than the supply available. The production of organic fertiliser usually depends upon the number of animals raised on any given farm. This in turn is related to the availability of animal feed and grazing land, as well as markets for the animal products.

Another well-known source of natural manure is the short-term cultivation of legumes to increase the soil nitrogen, through root nodules, before using the land for crop cultivation. Using water fern, *Azolla*, in rice fields is another means of enriching the nitrogen in rice fields. The nitrogen fixing ability of bacteria and blue-green algae is also being investigated with the objective of introducing other improvisations. The introduction of helpful mycorrhiza into soil also brings additional advantages in certain cases. The quantity of chemical fertilisers used is likely to increase in course of time as more and more land is brought under cultivation. New and safer varieties of fertilisers will have to be manufactured and made available at reasonable prices to farmers in the developing countries.

Energy is essential for agricultural production. In the developing countries, human energy is commonly used where the labour supply is sufficient and easily available. In addition, farmers use various types of animals, e.g. oxen, buffaloes, horses and mules. They are used for ploughing, or separating the grains from the straw, or for drawing water for irrigation. Draft animals are an essential part of many farms and their well being is important to the farmer to keep up his working schedule as planned. This situation is generally true in most of the developing countries, where draft farm animals are an asset, such animals also providing dung which can be used as manure for the crop plants.

The application of modern methods of crop improvement and the usage of machinery require greater energy inputs than traditional methods. It was realised a long time ago that usage of machinery was far more effective in cultivating vast stretches of land than using draft animals, but the operation is energy intensive and relies on the usage of fossil fuels or electrical energy. The former is much more convenient to use and comparatively cheaper than the latter. In well established systems, the quantity of food produced is directly correlated with the energy input. In terms of modern methods employed, saving of energy is only possible by using it more efficiently. In agriculture, the following types of energy are used: (a) solar energy; (b) the energy of fossil fuels, and (c) energy derived from human beings and animals. The energy used for the longest period of time in the history of agriculture is that derived from human beings and animals. It is sometimes argued that we should completely dispense with the use of fossil energy in

agriculture, using only animal and man power. It is possible to grow food without any machinery and chemical fertilisers, as was done in the past, or as is done in many developing countries to-day. These operations are very labour intensive and production levels very low. Such an approach world-wide would be ineffective in coping with the quantity of food required to feed the growing human population of the world.

People who live in extreme climatic conditions, e.g. the desert Arab or the Eskimo, have to work much harder, that is put more energy into obtaining just a frugal diet than do people in the more hospitable parts of the world. In these parts of the world, where food production is easier, the key factor as far as energy input and productivity are concerned, is the amount of food productive land available per head of population. A bushman in Africa can gather or produce enough food for a week for himself and two others by working only two days in a week. His energy output : input ratio, that is the ratio of metabolically-usable food energy he obtains to the energy he uses to get it, is 7.8 : 1, and the energy he uses in muscle power alone. An agricultural worker in the U.K. can produce enough food in one day for himself and forty-seven others. His energy output : input ratio is only 0.4 : 1 and the major part of the input is fossil fuel. So far as given input of energy, the bushman achieves about twenty times the output of the British agricultural worker. However, to do this the bushman needs 1040 hectares of land compared with 0.78 hectares used by the British agricultural worker. Clearly, this is important in a situation where world population is growing, and so the amount of food productive land per head of population is shrinking. Since energy in the form of fossil fuels is costly, and as a resource finite, clearly we need to know how fast and for what purposes we are using it in agricultural systems. Table 4 gives an example of the energy inputs to crop production for two crops in energy intensive systems in the U.S. and U.K. If we look at the energy needs involved in the use of pesticides, in both these cases, it is less than 2% of all the energy inputs for these crops. The energy equivalent of the additional weight of crop obtained when using pesticides in these cases more than compensates for the fossil fuel used in producing and applying the pesticides. It is possible to calculate the energy costs of various agrochemicals in a similar way and to measure these against improved productivity. E.g. Productivity in maize in the USA has been studied in response to the use of nitrogen fertilisers and the output : input ratio in this case is 8.86 : 1 for the first 50 kg/ hectare of nitrogen fertiliser applied. Clearly, in the case of these plant crops, the relatively small energy expenditure involved in using pesticides and nitrogen fertilisers is more than compensated for by the increased productivity. However, the figures for animal production are disappointing; for example, in the U.K. the energy output : input ratio, involving mechanical and chemical input for crop production is 3.2 : 1 but when animal production is included it falls to 0.4 : 1. This illustrates how much more expensive animal products are compared with plant products.

Table 4. Energy Inputs to Crop Production.

Input	U.S. Maize (1970) Oil Equivalent (gallons/hectare)	U.K. Potato (1972) Oil Equivalent (gallons/hectare)
Direct use of fuel	57.75	19.6
Fertilisers	76.51	27.3
Pesticides (production and application)	2.87	14.7
Machinery	30.45	24.15
Power	21.28	
Irrigation		9.38
Transport/Miscellaneous	21.00	5.04
TOTAL	209.86	87.15

The high cost of fossil fuels, especially petroleum, plays a critical role in agricultural economics, particularly in developing countries. These costs relate not only to the production of agrochemicals and the use of machinery directly to farming, but also to the costs of processing and distribution of food products. The urban areas are increasing throughout the world with the consequential increased energy needs of food storage and distribution. In developed countries, such as the USA, it has been demonstrated that energy plays an all pervasive role in industrialised agriculture. The use of energy in the USA has been analysed in relation to the different stages of food production :

Food preparation	uses	about	32.6%	of	total	energy
Food manufacture	"	"	24.2%	"	"	"
Agricultural production	"	"	19.6%	"	"	"
Distribution and transportation	"	"	22.4%	"	"	"
Waste disposal	"	"	1.2%	"	"	"

Put more simply, a standard wheat loaf requires four times as much fossil fuel in the milling, transport, baking and distribution as is used in growing the wheat, using tractors, fertilisers and pesticides.

CHAPTER 3

Agricultural Development and Food Production

Agriculture and Economics

The World Bank Report on Agriculture (1982) points out that farmers not only have to cope with the natural environment in which they work, that is the land, climate and soil, but also very importantly they have to adapt to changing economic circumstances. Indeed, the success or failure of particular agricultural practices depends upon the economic circumstances in which they are operated. The use of fertilisers, better seed, machinery and irrigation can significantly increase yield in agriculture in developing countries. However, such inputs need financing, before any output is available for sale, and the necessary capital investment is not always available. The population within a country will need food, but usually cannot afford to pay prices that would help further capital expenditure on farming. Many useful crops in the developing world are non-food crops, such as cotton, jute and rubber, which, however, have to compete with synthetically-produced materials. It is estimated that 70% of the population in the developing countries is engaged in agriculture, although the labour force is shrinking a little with industrialisation. Exports of agricultural products are an important means in the developing world of generating capital for investment leading to higher yielding agricultural practices. Out of 90 developing countries surveyed by the World Bank, in 10 more than 50% of agricultural output was intended for export, in 30 countries more than 20%, and in the other 50 countries just over 10%. Of course, the less developed the agriculture, the less likely it will be that exports are available, and so less capital will be available for further development.

However, world trading patterns are not always favourable for even those countries with products to export. The World Bank Report (1982) describes the experiences and price fluctuations of 1972-74, which created what could only be described as a 'world food crisis'. The price of wheat and rice increased threefold and that of fertilisers fourfold over this three-year period. The international market situation created very little incentive to produce more food or fertiliser in the developing countries. Grain stocks fell and prices escalated. Many countries bought more than they needed to avoid any possible scarcity, creating a food crisis in the market. Since then, some remedial measures have been taken in an attempt to regulate the situation. These include :

1. encouraging an increase in food production in appropriate regions;

2. monitoring of food stocks;

3. governments have been encouraged to cooperate in reaching agreements on improving food security and availability;

4. An international emergency food reserve bank has been established, with nearly 600,000 tons in reserve, with the International Monetary Fund food facility service assisting and managing the operation since 1981 (see Fig. 6).

The problems of developing agriculture are not simply technological but also socio-economic related to world trading patterns. Progress in

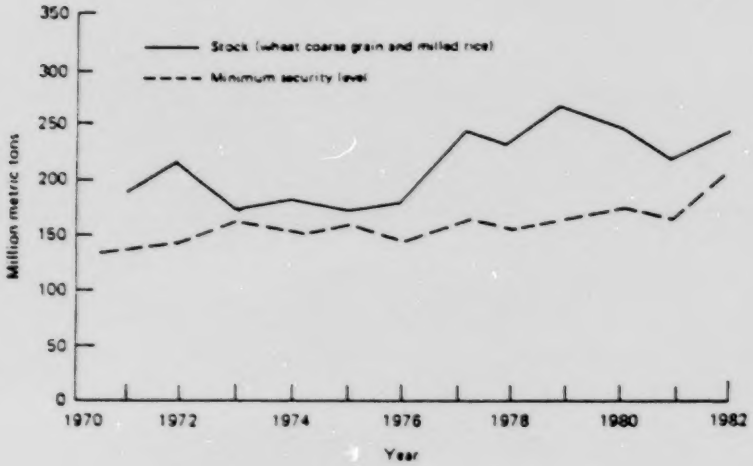


Fig. 6. World carryover stocks and minimum security levels of cereals (including China and the USSR): 1970-1982.

agriculture in developing countries was slow until about 1950. During the 1940's and 1950's, food production hardly kept pace with population growth. In the last thirty years, rapid development has taken place in many parts of the world due to technological advances and re-organised farming systems. In spite of this, however, in many developing countries, food production is still not adequate to cope with population growth.

Crop Zones

Five main crop zones have been identified in the developing countries and these are largely conditioned by soil and climatic conditions. They are : (1) the root crop zone of the humid tropics; (2) the rice zone of the humid tropics and temperate countries; (3) the maize zone of the sub-humid tropics; (4) the sorghum and millet zone of the semi-arid tropics; and (5) the wheat zone of the temperate and Mediterranean regions. The large agricultural bases of India and China are classified as mixed types. The total population, the agricultural population, population density, average yield of cereals and the land availability in these zones are shown in Table 5. As can be seen from this, outside India and China the largest density population exists in the rice-growing zone. Traditionally, rice was grown only in conditions of standing water.

Table 5. Different crop zones, total populations, population density per given area, the crop yield and arable land available for future improvement.

Crop zone	Predominant agroclimatic condition	Total population (millions)	Agricultural population (millions)	Agricultural population density (persons/ha)	Average yield of primary cereals (kg/ha)	Arable Land Reserves
Root crop zone	Humid tropical	193	120	1.6	750	Abundant
Rice zone	Humid tropical and humid temperate	574	358	3.5	2,050	Moderately abundant
Maize zone	Sub-humid tropical	353	161	1.1	1,450	Abundant
Sorghum and millet zone	Semi-arid tropical	86	70	1.6	670	Moderately abundant
Wheat zone	Temperate/ Mediterranean	395	182	1.0	1,850	Scarce
Mixed (India)	Warm temperate and arid to humid tropical	673	439	2.5	1,310	Very scarce
Mixed (China)	Cold temperate to sub-humid tropical	977	572	5.8	2,700	Very scarce

Sources: IFPRI; FAO.

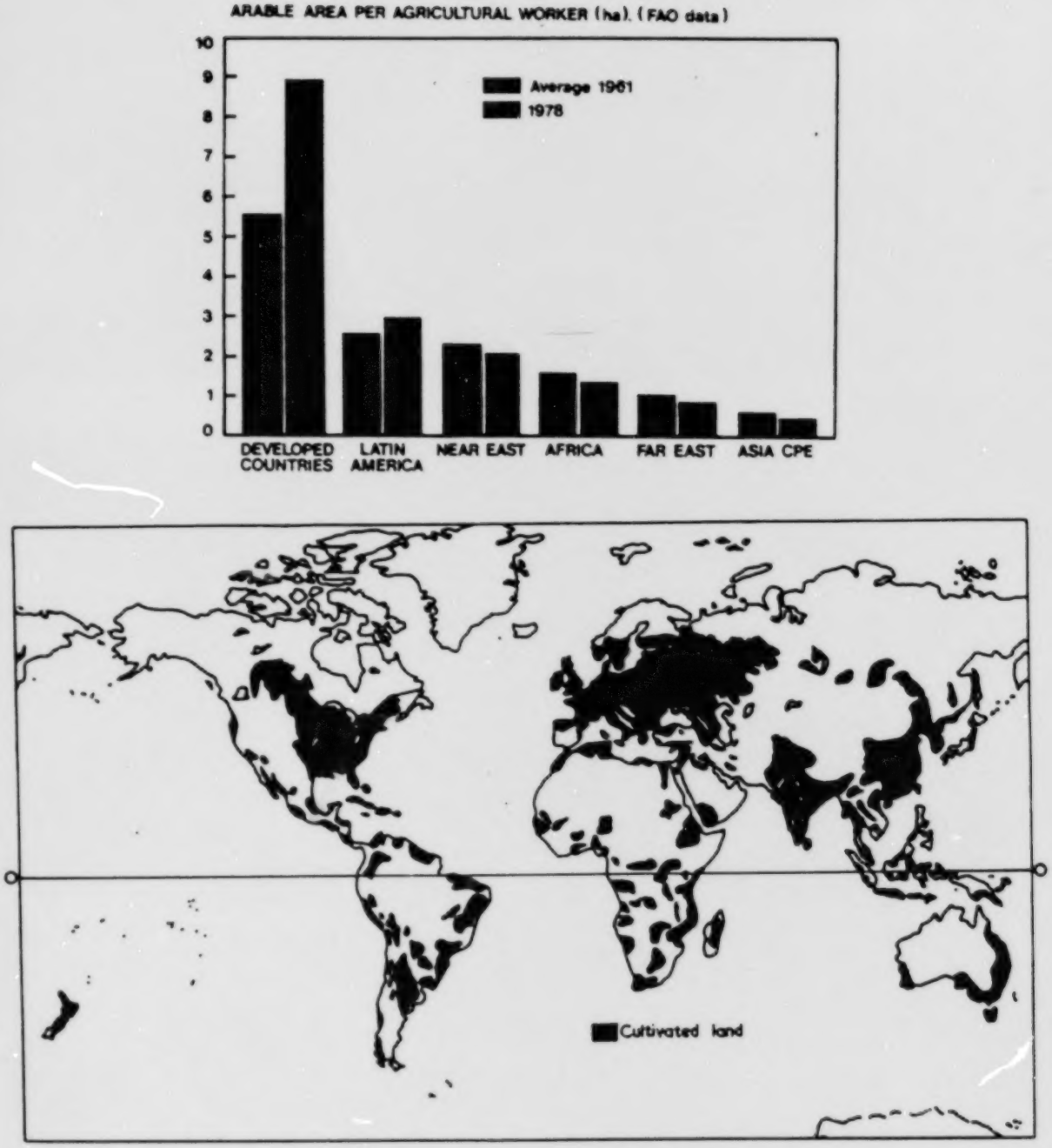


Fig. 7. Approximate area of cultivated lands in the world.

has wiped out many plant species completely and this is an irreparable loss. Timber extraction and fuel wood supply are often the main reasons for forest and clearance in many countries is not necessarily to provide new agricultural land. Forests are often cleared to such an extent that the cleared areas have become practically useless. Such areas are not suitable for agriculture because the soil is poor and heavy fertilising requires huge capital (Fig. 5). Almost 30% of the world population depends on firewood for cooking and heating. Gathering firewood is a full-time or part-time occupation to thousands of people in the developing countries. Cutting the trees and shrubs for firewood, with consequent destruction of the growing vegetation, has denuded forests. Soil erosion, sedimentation and

New varieties have now been developed which enable farmers to grow rice in relatively dry areas. Upland dry varieties, as well as submerged varieties, are now common. In the tropical crop zone, starchy root crops are now an alternative to rice. These can be grown on less fertile or poor marginal soils which are unsuitable for other crops. Cassava is such a crop which is an important export crop in many countries. Maize is the staple food in Latin American and African countries but is now cultivated alongside other crops, such as soybeans, sorghum, coffee, cocoa and cotton. With developing agricultural techniques, the crop zones are becoming more diversified.

Land Development

In the past, it was common practice, whenever higher production was required, to increase the area of agricultural land. Intensive agriculture is only a recent phenomenon. At present, about 820 million hectares of land is under cultivation and it is estimated that there are about 500-1,400 million hectares of arable land still available in many of the developing countries. Tending and cultivating the land is a slow process and for immediate use, i.e. before the turn of the present century, only 50-100 million hectares is likely to be brought under cultivation in Latin America and West Africa (Fig. 7).

In Asia and Europe, most of the suitable land is already used up. India and China are good examples, showing maximum land utilisation. In Indonesia, certain other island countries and in some regions of Asia, only the undisturbed forest land left may be opened up for agricultural purposes. In Central and West Africa, suitable stretches of land are available which could be brought under cultivation. WHO, FAO and the World Bank are helping many of the African countries to open extensive areas for cultivation. In these areas, attempts are being made to wipe out many of the local diseases, such as sleeping sickness, river blindness and malaria, so that people can move into them and cultivate the land. The cost involved in clearing such vast land areas is enormous and considerable research is required in order to bring under control organisms that cause human disease.

The governments in many developing countries, like Brazil, Malaysia, Indonesia, Nigeria and others, are helping and encouraging people to migrate into new areas and to cultivate the new farm land. New amenities are created by governments and small towns established with schools, hospitals, markets, etc. The cost involved is considerable, almost $1,000-2,000 per every hectare of land newly opened.

The opening of new land usually involves the clearing of forests and the problems connected with this deforestation have to be contained. Soil erosion, running off of the rain water, loss of plant wealth are some of the immediate problems and losses connected with deforestation. Indiscriminate clearing of forest

flooding are common resultant problems. The fertile cultivable land is also disturbed and as a result food production is affected. Such ecological destruction leads to a deterioration in the quality of life, as well as to an increase in poverty. If this continues unabated, many existing good crop lands will disappear or become uncultivable in two to three decades' time.

The fuel wood supply problem is a serious one and in many developing countries it is a matter of survival. Reforestation programmes have not been successful in many countries since the exposed soil is poor in nutrient contents and the rainfall is erratic. New water resources are necessary for many reforestation programmes. Farmers, local communities and their respective governments need to take urgent action to grow new types of trees for fuel or provide alternate energy supplies.

Agricultural Development and Productivity

The development of intensive agriculture and expansion of land use have been progressing in many countries for the last twenty years at an average annual growth rate of 2%.

Table 6. Rice production, area and yield in the Philippines: 1960, 1970, 1980[a].

Year	Production of rough rice (thousand tons)	Area (thousand ha)	Yield (t/ha)
1960	3,705	3,198	1.16
1970	5,343	3,112	1.72
1980	7,723	3,459	2.23

[a] About 3.2 million ha more would have been needed to achieve the 1980 production level at the 1960 yield level.

Source: Bureau of Agricultural Economics, Philippine Ministry of Agriculture.

Table 7. Impact of new technology on yield and land requirements in India.

	Year	Area (thousand ha)	Yield (t/ha)	Production (thousand tons)	Area (thousand ha)
Rice	1966-1970	36,360	0.98	35,770	-
	1979	40,480	1.33	53,770	14,331
Wheat	1961-1966	13,191	0.83	10,950	-
	1979	22,560	1.57	35,510	20,222

Source: Ministry of Agriculture, Government of India.

Three factors which contribute towards higher agricultural productivity are :

1. the development of water resources and irrigation and drainage systems;

2. the introduction of either new crops or varieties, and new livestock;

3. usage of agrochemicals.

Irrigation and Water Resources

Irrigation has long been seen as helpful in maintaining agricultural productivity but the new cultiuars available demand greater and more reliable water supplies than traditional varieties. Increased irrigation is possible by dam construction, water channel establishment and suitable canal systems. In many countries of Africa and Asia, agricultural productivity in the 1970's increased by two to three times when compared with past decades because of better use of water resources (Table 8). On irrigated land, two or three crops can be raised a year instead of one, and monsoon-dependent agriculture is a thing of the past in many regions. Almost one-fifth of the total agricultural land in developing countries is now irrigated to some extent and this has led to an average increase of 50-60% in agricultural output. China and India alone have 50 and 40 million hectares of irrigated land, respectively.

The initial development of irrigation systems is capital intensive and to provide irrigation for 50,000 hectares of land 100-200 million dollars have to be expended. Projects have to be carefully planned, if they are to justify such expenditure. Failure stories are very common in many developing countries. Poor design, the laying down of more canals than the supply can cope with, or neglect of the canal maintenance system are the usual reasons for the failure of a project. Inefficient use of water is common. Shallowing of canals by excess silt deposit, waterlogging, excess weed growth and increased salinity of the soil are the greatest hazards. The development of small scale irrigation systems is important; this is usually through the sinking of wells and can be facilitated by help to individual farmers.

However, more than 80% of agricultural activity is still dependent on rainfall directly. Of the four components involved in crop production, sun, seed, soil and rainfall, rainfall is the least predictable. Soil erosion and crop destruction, due to drought and flood, are the features in many parts of the world of rain-fed agriculture. Some progress has been made: it has been possible to improve the soil capacity to retain moisture by adding new compounds to change soil texture structure and texture, changing crops or rotating them at more frequent intervals can be helpful. Controlling flood and developing drainage systems has brought many improvements in countries such as Bangladesh, India and Thailand.

Table 8. Area, yield and production of rice (paddy) in developing countries: 1974-1976 and 2000.

Land and water class	Harvested area (million ha)		Yield (t/ha)		Production (million tons)	
	1974-1976	2000	1974-1976	2000	1974-1976	2000
Rainfed	62.6	57.8	1.5	2.1	95.4	123.8
Irrigated	36.5	64.8	2.7	4.1	97.6	264.9
Total	99.1	122.6	1.9	3.2	193.0	388.7

Source: FAO (1979).

Crop and Livestock Improvement

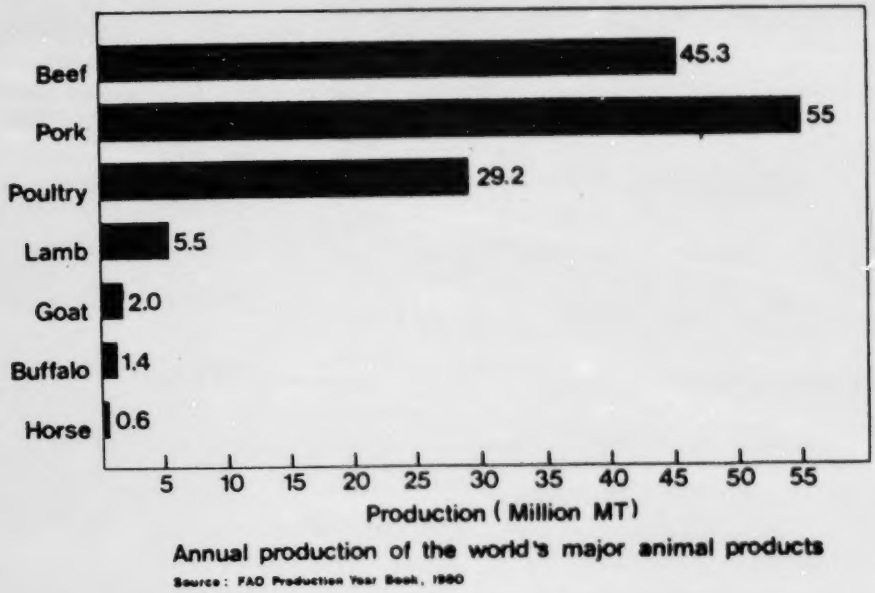
Due to good harvests in the last decade from 1971 to 1982, the world carry over stocks of wheat and rice are slightly above (230-300 million tonnes) the minimum security level (140-180 million tonnes). The rate of production varies from year to year. The present satisfactory situation only gives enough time to prepare and create enough buffer to meet the likely acute shortage in the future. The present rate of food production is above the rate of population growth and this has been made possible because of the following reasons :

1. Development of new high-yielding varieties of wheat, rice and some other food crops and livestock.

2. Continued efforts to maintain and improve agronomic practices.

Nevertheless, world food production, and especially that of the developing countries, is very limited. Most of the food produced and used by man comes from only 16 crop plants and 7 farm animals (Figs. 8 and 9). There has been no increase in their number or any remarkable varietal improvement in most of them. World food shortages are likely to be very acute, if one of the major crops like wheat or rice fails continuously over a period of two to three years.

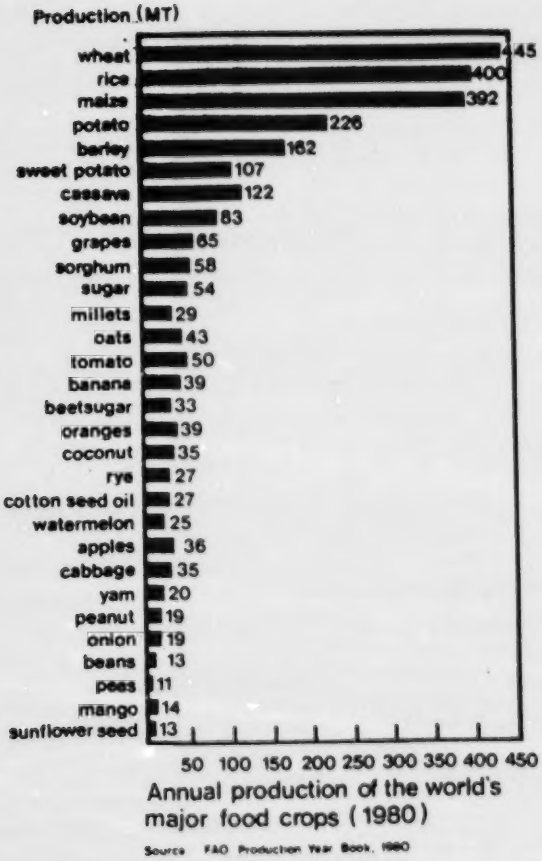
Various breeds of cattle and other farm animals have been raised that are suitable for different kinds of climate and land. Cross-breeding and composite breeding systems (intermating animals within two or three breeds) have been used to produce animals that are suited to various conditions and are highly productive. Animals are usually raised as protein food. More and more in the developing countries such animals are fed on cereal crops, although this is not necessarily the most efficient way of producing protein food, since 75-90% of the calorie content and 65-90% of the vegetable protein content of the cereal food is lost between the animal eating the cereals and animal protein being available for human consumption. Such developments have increased the pressure on the world's major cereal crops (Fig. 10).



Annual production of the world's major animal products

Source : FAO Production Year Book, 1980

Fig.8



Annual production of the world's major food crops (1980)

Source FAO Production Year Book, 1980

Fig.9.

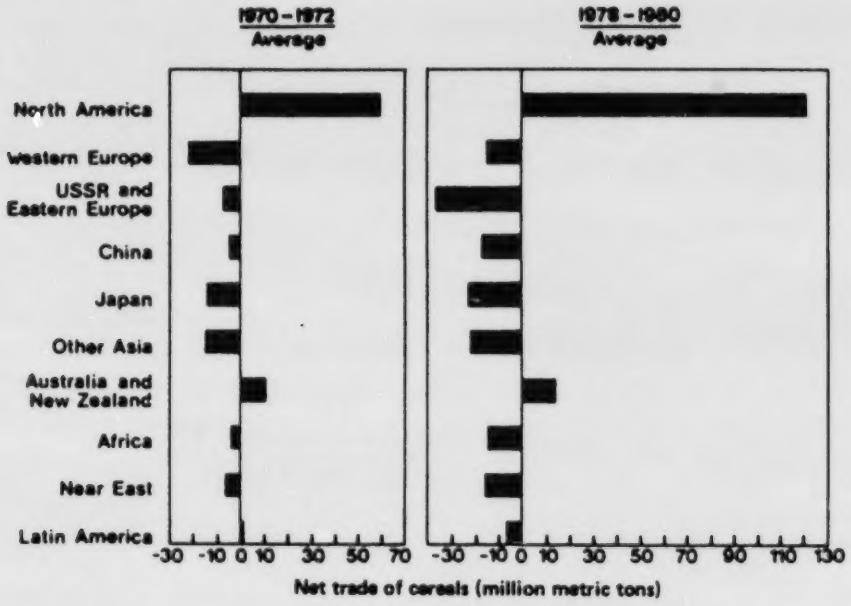


Fig. 10. Net trade of cereal grains (million tons): 1970-1972 and 1978-1980.

Agrochemicals

In addition to fertilisers, modern agriculture uses a range of agrochemicals as a means of increasing productivity. The majority of cultivated crop plants are the highly-selected varieties. In many cases they are more susceptible to insect and pest damage than the original wild species from which they were derived. It is estimated that pre-harvest loss may be very great in certain crops, almost up to 40%, especially in several tropical crop plants. Usage of pesticides and fungicides is common to prevent these losses and farmers in the developing countries have realised the value of crop protection. However, protecting crop plants from fungi, bacteria, virus and insects is a constant seasonal battle. The whole process involves interaction between elements such as soils, the plant, the pathogen and insects. The role of herbicides is also an important one to protect crops from weeds, which compete with them for space, nutrients and water.

The ability to alter the growth processes of plants can be used by farmers not only as selective weed-killers but also, for example, to increase the size of plants and their yield or to hasten or delay development and fruiting. Such substances used for this purpose are called plant growth regulators. In common terms, these chemicals are called plant hormones and were derived originally from naturally-occurring substances in plants. There are four groups :

1. Auxins - which bring out the enlargement of plant cells.

2. Gibberellins - which stimulate cell division and cell enlargement.

3. Cytokinins - which promote cell division.

4. Inhibitors - which inhibit or retard a physiological or biochemical process in plants.

Table 9 shows examples of the use of such substances in agriculture.

Table 9. Some of the common examples for the application of various growth substances and beneficial results.

	Name of plant/species	Chemical or common name of substance used	Beneficial results
1.	Onion	Maleic hydrazide	Prevent sprouting
2.	Pineapple	Naphthalene acetic acid; Ethephon	Induce flowering
3.	Apple, peach, pear	Alar	Flower induction
4.	Lettuce, radish, mustard, dill	Gibberellins	Induce flowering
5.	Sugar-cane	Maleic hydrazide; Dimethyl urea	Prevent flowering
6.	Orange	Abbott's release; Acti Aid	To induce fruit abscission
7.	Peach	Ethephon	Thinning agent
8.	Grapes	Gibberellic acid; Ethephon	Thinning agent
9.	Citrus	2,4-D	To prevent pre-harvest drop
10.	Tomato, squash, egg plant, fig	Naphthoxy; Chlorophenoxy; Acetic acid; Gibberellins	Fruit development
11.	Carrot	Gibberellins	Induce flowering
12.	Grapes	Gibberellins	To promote side branching
13.	Sugar-cane	Gibberellins	Increase cane size

Table 9 continued

	Name of plant/species	Chemical or common name of substance used	Beneficial results
14.	Wheat	Cycocel	Reduce stem length, prevent lodging, shorter plant, thicker stems, better filled heads
15.	Cotton, cucumber, grapes, hops, pumpkin, squash, tomato	NAA; Ethephon; Diamino zide	Change of sex in flowers
16.	Tobacco	Maleic hydrazide	To prevent formation of suckers. Improve leaf quality
17.	Citrus, tomato	Bio-regulator	Colour improvement
18.	Vegetables	Bio-regulator	Increase in vitamin content
19.	Sugar-cane	Bio-regulator	Increase in sugar content
20.	Rubber tree	Ethephon	Boost in latex production
21.	Sugar-cane	Glyphosine	Sugar-cane ripener

The use of fertilisers, pesticides, fungicides, herbicides and plant growth regulators can play an important part in contributing to higher agricultural productivity. However, the use of such agro-chemicals in developing countries is constrained by their costs and the degree of effectiveness of distribution systems.

CHAPTER 4

Biotechnology and Agriculture

Biotechnology

The field of Biotechnology is a vast one that includes several different types of technologies. Certain techniques, such as those involved in the production of alcohol and yoghurt, have been practised by man for a long time. Others, like plant tissue culture, recombinant DNA techniques, single cell protein production and modern methods of antibiotics production, are relatively new and they hold great promise for the future. Alcohol, as a fuel, has gained in economic importance since oil prices were sharply increased, and in some countries the sugar-cane industries have been developed in order to supply ethanol as fuel alcohol. Agriculture-based raw materials are used in varying proportions for the production of antibiotics, various enzymes, amino acids and various other organic acids. The use of techniques for the improvement of strains of crop plants and farm animals, fermentation processes to convert agricultural waste and wood products into useful materials, production of protein-rich materials from single cells for animal feeds are examples of the increasing economic importance of biotechnology.

Plant Tissue Culture

Plant tissue cultures are usually established by incubating sterilised pieces of tissue (leaf, stem, root, etc.) on a solid nutrient medium. A number of techniques of plant tissue culture have potential consequences for agricultural practice. Since most commercially important crops are seed propagated, the mass propagation of such crops by tissue culture is likely to be less useful than clonal improvement. However, clonal propagation by tissue culture is likely to be useful for some crops. Tissue culture techniques are making it possible, for instance, to produce uniform clones of high-yielding, top quality oil palms, a plant for which there is no convenient method for vegetative propagation.

Techniques for the improvement of crop varieties, using either pollen culture or protoplast culture, have been developed and hold much promise. The production of haploid plants, and through this the establishment of homozygous breeding lines, is now a powerful technique for crop improvement. Considerable success has been achieved with haploid barley plants that were obtained by crossing *Hordeum vulgaris* and *Hordeum bulbosum*. The double haploids that were produced proved very suitable both for cultivation and variety improvement. A potentially important application of plant tissue culture techniques is in the use of meristem culture for virus elimination. This technique is likely to be a great value in fruit farming.

Germplasm conservation of crop plants has become a major problem since it is costly in time, labour and space. The use of tissue culture techniques for the storage of germplasm has considerable potential. The technique involves tissue culture and freezing; tissues of many of the agriculturally important woody species, such as coffee, can be stored for up to two years in this way.

Plant protoplast isolation, a relatively new technique, offers interesting opportunities for future plant improvement. It has been shown that isolated protoplasts from either the same species, different species and even sometimes different genera, can be induced to fuse with one another. The development of this technique offers the possibility of inducing somatic hybridisation, leading to a variety of crop improvements, such as disease-resistance, hybrids between legumes and non-legumes, and increased photosynthetic efficiency.

Table 10. Crop species from which protoplasts have been isolated and cell/plant regeneration observed.

Plant species	Tissue origin	Plant regeneration
Solanum tuberosum, potato	leaf	P.
Lycopersicon esculentum, tomato	leaf	P.
Hordeum vulgare, barley	cell culture	
Zea mays, corn	shoot	
Pennisetum americanum, millet	cell culture	
Oryza sativa, rice	callus	
Sorghum bicolor, sorghum	cell culture	
Triticum spp., wheat	cell culture	
Asparagus officinalis, asparagus	callus, cladodes	P.
Brassica napus, rape	leaf	P.
Daucus carota, carrot	cell culture	P.
Pisum sativum, pea	shoot tip	
Medicago sativa, alfalfa	leaf	P.
Glycine max, soybean	cell culture	
Vicia faba, faba bean	leaf	
Phaseolus vulgaris, bean	leaf	
Vigna sinesis, cowpea	leaf	
Linum usitatissimum, flax	hypocotyl	
Gossypium hirsutum, cotton	callus	
Citrus sinensis, orange	callus	P

The breeding and selection of a new variety of crop plant is a slow process. Rice is an interesting example; it has been shown that it takes about 7-8 years to obtain a genetically suitable strain and to adopt it for cultivation. The rice variety IR-36 produced

Table 11. Reports on protoplast fusion and heterokaryocyte division involving different plant genera.

Source of protoplast	
Barley *(Hordeum vulgare)*	• Soybean *(Glycine max)*
Corn *(Zea mays)*	• Soybean *(Glycine max)*
Pea *(Pisum sativum)*	• Soybean *(Glycine max)*
Alfalfa *(Medicago sativa)*	• Soybean *(Glycine max)*
Caragana *(Caragana arborescens)*	• Soybean *(Glycine max)*
Rapeseed *(Brassica napus)*	• Soybean *(Glycine max)*
Tobacco *(Nicotiana tabacum)*	• Soybean *(Glycine max)*
Nicotiana glauca	• Soybean *(Glycine max)*
Secale cereale	• Soybean *(Glycine max)*
Colchicum autumnale	• Soybean *(Glycine max)*
Nicotiana langsdorffii	• Soybean *(Glycine max)*
Faba bean *(Vicia faba)*	• Petunia *(Petunia hybrida)*
Sorghum *(Sorghum bicolor)*	• Corn *(Zea mays)*

Table 12. Important crop species for which plant regeneration has been achieved from directly isolated protoplasts.

Plant	Species	Source
Asparagus	*Asparagus officinalis*	cladodes
Cassava	*Manihot esculenta*	leaf
Potato	*Solanum tuberosum*	leaf
Rapeseed	*Brassica napus*	leaf
Tomato	*Lycopersicon esculentum*	leaf

at IRRI, Philippines, is an excellent example of such a strain which is now extensively cultivated in Asia, with a total acreage of 10 million hectares. Corn is another example which took about 12 years to produce a variety improved for high lysine content. Many aspects of biotechnological methods were used in developing both these crop plants. Tissue culture and genetic engineering techniques hold great promise for the future of crop improvement. With rice, for example, through tissue and cell culture, better varieties of plants can be produced. It should be possible to produce varieties which will be (a) tolerant to aluminium toxicity and excess salt conditions; (b) mutationally superior with higher lysine and protein content; and (c) resistant to different kinds

of diseases. Using embryo culture techniques, new hybrids may be produced at both infra- and inter-specific levels. Anther and pollen culture techniques can be used in attempts to reduce breeding time. The modification of single cells or somaclonal techniques holds great promise for rice improvement. Superior cells, when identified and selected, can be used to obtain better plants through single cell culture techniques. Cell suspension cultures and callus cultures can also be effectively used to generate better varieties of plants. The induction and selection of useful mutants, both at cellular and tissue levels, also hold great promise in rice breeding programmes.

Tissue culture techniques can be directly applied to breeding perennial crop plants like coconut, rubber and others. The coconut palm, for example, suffers from several diseases like root wilt and the drying up of the inflorescence. There are usually a few healthy disease-resistant palms to be found, even in an heavily infested coconut plantation. Since coconut is a cross-pollinated plant, it is difficult to isolate the wanted genotypic plant. Therefore, if the disease-resistant varieties are cloned through tissue culture, either by using the root or the inflorescence meristems, the regenerated plants will be disease-free and suitable for mass propagation.

Genetic Engineering

The importance of the application of the results of research in genetic engineering to crop improvement has recently been emphasised in literature on agriculture and biology. The improvement of crop plants through genetic engineering involves the artificial transfer of naturally-occurring genes to crop plants, usually from their uncultivated relatives. Collections of identified and tested germplasm can be used for breeding in the traditional way, as well as through the new methods of molecular biology. The transfer of genes within cultivated varieties will bring about some improvements in crop quality, but the introduction of new qualities requires the use of a wider germplasm collection, and this involves the new method derived from molecular biology.

The new developments in genetic engineering offer the means by which segments of DNA (vector genes) may be transferred from one plant species to another. Vector genes are isolated from plants that have desirable qualities, such as the potential for disease resistance, drought and herbicide tolerance, improved photosynthesis, better fertiliser utilisation, symbiotic nitrogen fixation and others. Appropriate DNA segments from such plants are then transferred to the crop plant. Crop plants with better disease resistance or producing new non-leguminous plants that can fix nitrogen are the present-day aims of plant genetic engineers. To transfer genes from one plant species to the other, protoplasts are used, since the cell wall creates an impediment either for removing or adding the genetic material from or to a given cell. The technique of protoplast culture *in vitro* holds great promise. There is no reason to doubt that by the turn of the present century the scientists will be able to synthesise better strains of crop plants using these techniques.

Biofertilisers

The use of leguminous plants for enriching the nitrogen content of the soil is a widely developed agricultural practice. Leguminous plants develop root nodules; these nodules are the site of nitrogen fixations. Symbiotic soil bacteria help in this process of nodulation. For many of the well-known leguminous crops, like soybean and peanut, the associated bacteria have been identified. Both the seeds, together with the best-suited nodulating bacteria, can now be purchased. The selected bacterial strains at present available are not only efficient for root nodulation but they are also resistant to bacteria which are hostile to the host plants.

All crops are dependent upon nitrogen and many, unlike the leguminous plants, are dependent upon fixed nitrogen. The use of nitrogen fertilisers is an essential, and costly, feature of the cultivation of many crops. Clearly, if attempts to induce nitrogen fixing nodule formation in common crops such as corn (see above) are successful, the input costs of agriculture can be expected to fall sharply. In addition to this, a number of other techniques are being developed.

Blue-green algae are used to produce fixed nitrogen in rice cultivation in several countries. Blue-green algae are grown in rice fields in Burma, China, Egypt and India, with a consequent improvement in yield of up to 16%.

Many species of *Azolla*, the water fern, are suitable for use in nitrogen fixation for rice culture. *A. pinnata* and *A. filiculoides* produce 3 and 10 kg N/ha, respectively. In China and Vietnam, using *Azolla* in rice fields has been a common practice for many decades. Many other countries now have also adopted this method. Its effectiveness can be equivalent to using 30 kg N/ha of urea; experience gained in the Philippines has shown that urea or other nitrogen fertilisers can be completely replaced if *Azolla* is used twice during each period of rice cultivation. Varieties of *Azolla*, with superior nitrogen fixing abilities, are likely to be produced soon by protoplast fusion.

A bacterium, *Azospirillus*, has proved effective in developing some nitrogen fixation in rice plants. This bacterium, isolated from the roots of other plants, was inoculated into the roots of rice plants with somewhat variable, but encouraging, results.

The use of certain aquatic papilionaceous plants like *Aeschynomene*, *Neptunia* and *Sesbania* as green manure is common in India. Before the planting season, these plants are grown in the rice field for a short period and then the land is ploughed so that the vegetative parts of the plants are well mixed with soil. These plants are well known for both their stem and root nodule producing potential. Both the nodules, as well as the vegetative remains, enrich the nitrogen content of the soil. Many of these techniques need further research and development, but they suggest important future possibilities for agricultural practice.

Plant Physiology, Genetics and Food Production

Agricultural scientists and farmers aim to obtain the maximum possible yield for any given crop. The use of fertilisers, herbicides, pesticides, plant growth regulators and proper irrigation and drainage can all play their part in achieving higher yields from crops. However, these can only work if used in conjunction with a knowledge of the genetic qualities and growth properties of plants. Continuing research in plant physiology and genetics and its application to agricultural practice is a vital factor in the development of stable, high yielding agricultural systems. Further increases in the potential yield of rice, for instance, could be achieved through more research into increased biomass production through, for example, faster leaf area development, lower respiration rates, larger spikelet numbers per shoot, larger grain size, shorter plants with a stronger culm. The development of plant tissue techniques suggests the possibility of quite novel methods of using plant cell cultures directly for the economic production of food products. All these techniques have considerable consequences for future agricultural development.

Animal Husbandry

New techniques derived from modern developments in biotechnology have some significance for the future of animal husbandry. Some of these are likely to be directly related to animal husbandry, others more indirectly. The use of sperm banks and artificial insemination have been used successfully for livestock improvement for a long time. More recently, embryo transfer techniques have been used in improving the quality of milk cows. A cow, known for its high milk production, is treated with fertility drugs before fertilisation. Consequently, 6 to 8 embryos will be produced instead of the usual one. Another technique for producing more embryos is by increasing the periodicity of ovulation, inducing egg production once in 2-10 weeks. The embryos so produced are removed from the donor cow and implanted in the uterus of less valuable cows. Thus, many improved calves can be produced within a short period from one good milking cow using surrogate mothers. Similar techniques have been used to improve the quality of sheep, goats, rabbits and pigs. The technique has been extended so that, by using deep freezing, embryos can be stored for transportation. In this way, livestock improvement centres can supply potentially improved livestock cheaply over long distances easily.

Intensive livestock farming relies on the availability of adequate animal feed, and the use of antibiotics, hormones and vaccines. The new techniques, derived from molecular biology, that are now developing, are likely to give, indirectly, support to such forms of animal husbandry. Intensive agriculture has tended to use grain as the basis for animal feed in order to achieve high productivity. This is costly and, in the developing countries in particular, competes with the need to use limited grain stocks for

feeding people. In such cases, farmers have to resort to using hay and other cellulose materials, often of low nutritional value, with an ensuing low yield of animal products, such as meat or milk. Microbial engineering, using recombinant DNA technology, offers the possibility of deriving nutritionally high value animal feed from lignocellulose.

Intensive animal units produce large quantities of effluent, which, while of great potential as fertiliser, provides in such quantities difficulties of treatment. New techniques being developed from the treatment of such wastes are based on microbial engineering, as are attempts at developing means of producing hormones, vaccines and antibiotics.

Food Losses after Harvest

Efforts being made to augment food production to meet increasing demand will be only of limited success unless efforts are also made to prevent food losses after harvest. In general, the post-harvest food loss is quite significant in developing countries, Tables 13, 14, 15). Many of the reasons for this are due to organisational problems, such as poor transport and lack of adequate storage facilities. Over the last fifteen years, research has been developing into the post-harvest physiology of fruits and seeds, considering the possibilities, for instance, of extending the ripening process of reducing respiratory loss. Such work may be ehlpful in the development of cheap and simple techniques that could be applied in developing countries to help maintain both the quality and quantity of food after harvesting.

Table 13. Non-grain staples, vegetables and fruit losses reported by region and country. (From FAO, 1977b, unless otherwise indicated.)

Region/ country	Roots/ tubers (% loss)	Fruits/ vegetables (% loss)	Remarks
AFRICA			
Ghana	10-20	30-35	
Nigeria	15-60		Yams, Clorunda (1977)
	10-50	10-50	
Rwanda	5-40	5-40	
Sudan		50	Lack of transport to market
ASIA/FAR EAST			
Sri Lanka		20-40	
Thailand		23-28	
Indonesia	10	25	Cassava
		15-25	
Philippines		10-50	
Malaysia		20	
India		20-30	
Jordan		2-3	Lack of cold storage
Iran	5-100	5-10	Frost in potatoes, Steppe (1976)
		14-28	Subtropical fruits

Table 13 continued

Region/ country	Roots/ tubers (% loss)	Fruits/ vegetables (% loss)	Remarks
LATIN AMERICA			
Dominican Republic	24-26	25	Except plantain-10; tomatoes-13; green beans-12
	17		Cassava, Tejada (1977)
Chile	30	30	Potatoes
Brazil	5-30	8-10	Cassava-10; potatoes-5-30; pineapple-8; banana, tomatoes, orange-10
Bolivia	24	17-30	Potatoes-24; citrus-27; tomatoes-30; pineapple-17
Peru	20-50		Potatoes, Werge (1977)

Table 14. Non-grain staples, vegetables and fruits
Losses reported by commodity

Commodity	Production in LDCs* ('000 tonnes)	Estimated loss (%)	Remarks
ROOTS/TUBERS			
Carrot	557	44	Thompson, in Coursey (1971)
Potatoes	26,909	5-40	8% in cold store; 20-40/ on farm; FAO (1977b)
Sweet potatoes	17,630	35-95	Thompson, in Coursey (1971); Hall (1970)
Yams	c.20,000	10-60	FAO (1977b); Olorunda (1977)
Cassava	103,486	10	Indonesia, Brazil, FAO (1977b)
		15-25	(see text)
VEGETABLES			
Onion	6,474	16-35	Thompson, in Coursey (1971);
Tomatoes	12,755	20-50	Steppe (1976)
		5-16	Thompson, in Coursey (1971); Steppe (1976); Olorunda (1977)
Plantain	18,301	35-100	In transport only, Rawnsley (1969)
Cabbage	3,036	37	Olorunda (1977)
Cauliflower	916	49	Thompson, in Coursey (1971)
Lettuce		62	Thompson, in Coursey (1971)
FRUITS			
Banana	36,898	20-80	Olorunda (1977)
Papaya	931	40-100	Olorunda (1977)
Avocado	1,020	43	Thompson, in Coursey (1971)
Peaches, apricots, nectarines	1,831	28	Steppe (1976)

* Less developed country figures taken from FAO, 1977a.

Table 14 continued

Commodity	Production in LDCs* ('000 tonnes)	Estimated loss (%)	Remarks
FRUITS			
Citrus	22,040	23-33	Steppe, Iran (1976)
		20-95	Olorunda, Nigeria (1977)
Grapes	12,720	27	Steppe (1976)
Raisins	475	20-95	Steppe (1976)
Apples	3,677	14	Steppe (1976)

* Less developed country figures taken from FAO, 1977a.

Table 15. Reported losses of wheat and barley, millets, and sorghum within the post-harvest system (based on FAO, 1977b, figures unless otherwise indicated).

Commodity and country	Total % weight loss	Reported national production ('000 tonnes)	Remarks
WHEAT			
Pakistan	5-10	8,500	On-farm storage 5-10; milling 2; central store 5 (Qayyum, 1977; Greaves, 1977; Chughtai, 1977)
	12		Unspecified storage
India	8-25	24,000	(Amla, 1977; Agrawal, 1977)
	2-52		Farm storage to 45; threshing 1; central storage 8
Rhodesia	10	2,571	On-farm storage (Howden, 1977)
Sudan	6-19	880	
Bolivia	16	833	Storage 7; drying 3
Brazil	15-20	906	Storage 1-4
BARLEY			
Pakistan	9	130	Unspecified storage 7; processing 2
Bolivia	14	80	Drying 2; unspecified store 6; transport and distribution 4
Sudan	17	-	Central store
MILLETS			
Mali	2-15	804	On-farm store 2-4; central store 10-14 (Guggenheim, 1977)
Nigeria	0.1-0.2	3,200	On-farm storage
Rhodesia	10-15	564	On-farm storage (Howden, 1977)
Sudan	14	450	Central store
Zambia	10	30	On-farm storage
India	7-10	9,600	Drying 2-5; farm storage 5 (Chaturvedi, 1977; Agrawal, 1977)
Pakistan	7.5	503	Storage 5; processing 2.5

Table 15 continued

Commodity and country	Total % weight loss	Reported national production ('000 tonnes)	Remarks
SORGHUM			
Nigeria	0-37	3,680	On-farm over 26 months (Hall, 1970)
Rhodesia	25	716	On-farm store (Howden, 1977)
Sudan	6-20	1,800	Central storage
Zambia	0-10	46	Local varieties, negligible; high-yielding varieties 10 (TPI, 1977)
India	7.5	544	Unspecified storage
Indonesia	4.0	-	
Pakistan	7.0	621	Storage 5; processing 2

Table 16. Reported losses of rice within the post-harvest system (based on FAO, 1977b), figures unless otherwise indicated)

Region and Country	Total % weight loss	Reported national production ('000 tonnes)	Remarks
West Africa	6-24		Drying 1-2; on-farm storage 2-10; parboiling 1-2; milling 2-10 (van Ruiten, 1977)
Sierra Leone	10	580	
Uganda	11	15	
Rwanda	9	5	
Sudan	17	7	Central storage (Kamel, 1977)
Egypt	2.5	2,300	
Bangladesh	7	18,500	
India	6	70,500	Unspecified storage
	3-5.5		Improved traditional storage (Boxall and Greeley, 1978)
Indonesia	6-17	22,950	Drying 2; storage 2-5
Malaysia	17-25	1,900	Central store 6; threshing 5-13;
	c.13		Drying 2; on-farm store 5; handling 6 (Yunus, 1977)
Nepal	4-22	2,404	On-farm 3-4; on-farm store 15; central store 1-3
Pakistan	7	3,942	Unspecified storage 5
	2-6		Unspecified storage (Qayyum, 1977)
	5-10		Unspecified storage 5-10 (Greaves, 1977)
Philippines	9-34	6,439	Drying 1-5; unspecified store 2-6; threshing 2-6
	up to 30		Malaysia workshop (FAO, 1977c)
	3-10		Handling (Toquero *et al.*, 1977)

Table 16 continued.

Region and country	Total % weight loss	Reported national production ('000 tonnes)	Remarks
Sri Lanka	13-40	1,253	Drying 1-5; central store 6.5; threshing 2-6
	6-18		Drying 1-3; on-farm store 2-6; milling 2-6; parboiling 1-3 (Ramalingam, 1977)
Thailand	8-14	14,400	On-farm store 1.5-3.5; central store 1.5-3.5
	12-25		On-farm store 2-15; handling 10 (Dhamcheree, 1977)
Belize	20-30	2	On-farm storage (Cal, 1977)
Bolivia	16	113	On-farm 2; drying 5; unspecified store 7
Brazil	1-30	9,560	Unspecified store 1-30
Dominican Republic	6.5		On-farm store 3; central store 0.3

CHAPTER 5

Agriculture, People and Food

Malnutrition

According to the World Bank Report of 1980, nearly 50% of the world population lives in absolute poverty or very close to that level. The average income of about 900 million people is about less than $100 per year and of these about 700 million get less than $60. Nearly 50% of them are in South Asia, India, Bangladesh and another 40% in South East Asia and African countries bordering Sahara desert. The last 10% are in Latin America, North Africa and Middle East. This low income poverty level is very closely related to hunger and malnutrition. The malnutrition is related to both total intake of food (quantity) as well as to lack of protein in the diet (quality).

Dietary deficiencies cause serious health problems and nutritional imbalances lead to deficiency diseases. It is well-known that deficiencies in vitamin A, iron and folic acid cause severe anaemia and endemic goitre (due to iodine deficiency). Acute vitamin A deficiency even causes blindness, as medical reports from many developing countries of South and South East Asia reveal. Anaemia is very common in Latin American countries. More than half the child deaths in Latin America are due to nutritional deficiencies, and more than 50% of the children in developing countries are under-nourished.

Protein Foods

Of late, many attempts are made to increase the production of protein foods. Single-celled algae are grown in tanks and other man-made situations and these are fed to farm animals, which in turn provide milk or meat, as the case may be. Nearly 50% of the fish catch is discarded as unsuitable for human consumption and yet this could be used to prepare fish meal, rich in protein. The fish industry could be remodelled, since almost all parts of the fish can be reprocessed and eaten in the modified form. Fish farming is becoming very popular, even in many developing countries, and nearly 30-40% of fish consumed originate from established farms. Tropical seas and freshwaters are very suitable for various kinds of aquaculture. Over-fishing of the sea exists and this, together with establishing territorial rights for fishing, are international problems. However, many new developments in the form of research are being made to increase the population of fish in the sea to make up the dwindling resources, and basic research conducted in developing countries is providing useful solutions to many local problems.

Similarly, new agricultural methods aim at improving plant protein resources. It is realised that by using different crops, the protein yield per given land area may be increased and quantitatively protein yield from plants is much higher than from animals per given hectare, and the cost of production is cheaper using plants than animals.

Table 17. Protein yield from plant and animal sources.

Source	kg/hectare
Soyabean	510
Sunflower	380
Cotton seed	270
Broad bean	260
Corn	200
Rice	190
Wheat	150
Oats	90
Milk	50
Poultry	40
Pigs	30
Beef	25

Food Zones

The different countries of the world have been classified into nine food zones, depending on the major items of staple diet in each zone (Table 18). The percentage contribution of different foods to the total intake of energy and protein is also calculated. In developed countries, where meat, fish, egg and milk (protein foods) intake is high, the usage of cereals, pulses and nuts is very much lower, whereas in developing countries the condition is reversed. This affects the caloric value, quantity and quality of food consumed by populations in various countries (Table 19).

Kinds of Food

Different kinds of food are required for the functioning of the human body. For muscular work and adequate energy, carbohydrates and fats are required. Carbohydrate in the form of refined sugar, sucrose, is obtained from sugar-cane or beetroot; fruits, vegetables and honey are the other sources for sugar. The major source of carbohydrate is starch, consumed either as bread, rice, noodles, cereals, potatoes, bananas, yams and tapioca. The fat component of food mostly comes from animal sources like milk and butter. The cooking oils are mostly of vegetable origin, like groundnut, soyabean, coconut or oil palm, sesame and sunflower. Proteins are important

Table 18. World Food Zones (FAO).

Food zone		
A	Animal foods:	Australia, Austria, Canada, Denmark, Finland, Iceland, Ireland, Netherlands, New Zealand, Norway, Panama, Paraguay, Puerto Rico, Sweden, United States, Uruguay
B	Animal foods/ wheat:	Albania, Argentina, Belgium-Luxembourg, Bolivia, Bulgaria, Chile, Cost Rica, Cuba, Czechoslovakia, France, German Democratic Republic, Federal Republic of Germany, Greece, Hungary, Israel, Italy, Jamaica, Malta, Peru, Poland, Portugal, Romania, Spain, Switzerland, Trinidad and Tobago, USSR, United Kingdom, Venezuela, Yugoslavia.
C	Animal foods/ cereals other than wheat:	Colombia, Dominican Republic, El Salvador, Guyana, Hong Kong, Japan, Mongolia, Philippines, Singapore, Somalia, South Africa, Sudan, Surinam, Tanzania, People's Democratic Republic of Yemen.
D	Wheat:	Afghanistan, Algeria, Cyprus, Egypt, Iran, Iraq, Jordan, Lebanon, Libyan Arab Republic, Morocco, Pakistan, Syrian Arab Republic, Tunisia, Turkey.
E	Rice:	Bangladesh, Burma, Indonesia, Khmer Republic, Laos, Liberia, Madagascar, Malaysia (West), Sabah, Sarawak, Sierra Leone, Sri Lanka, Thailand, Democratic Republic of Vietnam, Republic of Vietnam
F	Mixed cereals:	Burundi, China, Ethiopia, Guinea, India, Democratic People's Republic of Korea, Republic of Korea, Mauritius, Mozambique, Nepal, Saudi Arabia.
G	Millet:	Chad, Mali, Mauritania, Niger, Upper Volta, Yemen Arab Republic
H	Maize:	Kenya, Malawi, Mexico, Zambia, Zimbabwe
I	Animal foods/ roots/cereals/ pulses:	Angola, Brazil, Cameroon, Central African Republic, People's Republic of Congo, Dahomey, Ecuador, Gabon, Gambia, Ghana, Guatemala, Haiti, Honduras, Ivory Coast, Nicaragua, Nigeria, Rwanda, Senegal, Togo, Uganda, Zaire

Table 19. Percentage contribution of different foods to total intake on energy and protein in classified food zones.

Food zone	Cereals		Starchy roots		Sugar		Pulses and nuts		Fruits and vegetables		Meat and fish		Eggs and milk		Fats and oils	
	Energy	Protein	Energy	Protein	Energy	Protein	Energy	Protein	Energy	Protein	Energy	Protein	Energy	Protein	Energy	Protein
A	20	17	4	3	17	-	3	4	5	5	20	41	14	30	17	-
B	39	39	7	5	13	-	3	4	4	4	11	26	10	22	13	-
C	51	41	7	2	12	-	4	11	5	6	8	27	6	13	7	-
D	64	67	1	1	10	-	4	7	5	5	3	8	5	12	8	-
E	71	64	7	3	5	-	5	12	3	3	3	13	2	5	4	-
F	68	60	8	4	5	-	7	18	2	4	4	9	2	5	4	-
G	73	62	2	-	3	-	12	20	1	1	4	11	3	6	2	-
H	56	54	3	1	-	-	8	18	4	1	6	17	4	9	5	-
I	36	37	25	12	9	-	8	20	6	4	6	19	3	8	7	-

for growth and animals are the chief sources of such food, although animal protein is more expensive to produce than plant protein. The leguminous seeds (beans), certain cereals and nuts are the main sources of plant protein. They are usually consumed as cooked food in a wide variety of dishes. Fruits and vegetables, of various kinds, provide the necessary vitamins required by the body. The cellulose component of such food is also important in that it helps the food movement in the digestive tract. Over a period of time, different kinds of food have evolved in various countries and social customs and religious beliefs strongly govern the feeding habits of people throughout the world.

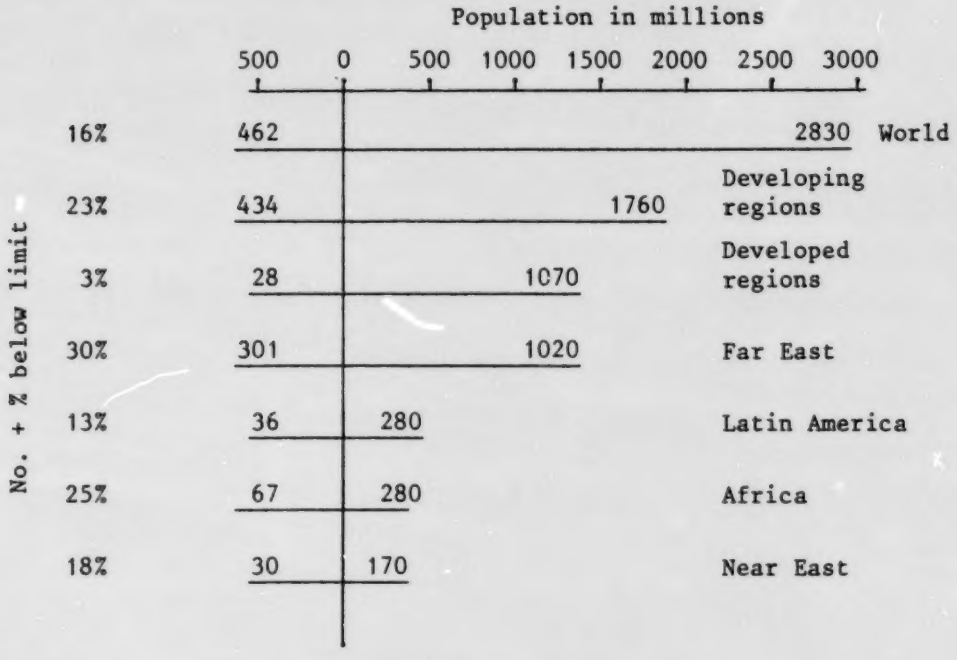
It is very difficult to define the nutritional needs of any group of people because of the number of variables involved; these are such as body weight and shape, type of activity, age and climate. One method of measuring food intake is by the energy content of food. The present FAO estimates of daily energy requirements per person is between 9,000 and 12,000 kilojoules. The estimate for the developed world is about 10,900 kilojoules, while that for the developing world is 9,700 kilojoules. This apparently inequitable distribution of needs is because the people in the developed countries, on the whole, have heavier bodies and so need more food to carry the extra weight!

Table 20. Average food, energy and protein supplies per person by region, 1961 and 1969-71.

	Energy (kJ per person)		*Protein* (g per person)		*Energy as percentage of requirement*	
	1961	*1969–71 Average*	*1961*	*1969–71 Average*	*1961*	*1969–71 Average*
Developed market economies	12 330	12 920	87.5	95.1	115	121
Western Europe	12 620	13 080	89.3	93.7	118	123
North America	12 000	13 880	92.3	105.2	112	126
Oceania	13 420	13 630	92.7	108.1	121	123
Other developed market economies						
Japan, Israel, South Africa	10 120	10 660	73.3	79.1	102	108
Developed centrally planned economies						
Eastern Europe and USSR	12 500	13 630	85.8	99.3	116	127
Total developed countries	12 370	13 170	87.0	96.4	116	123
Developing market economies	8 900	9 240	55.0	56.0	93	97
Africa	8 860	9 150	55.7	58.4	91	94
Far East	8 570	8 690	51.3	50.7	92	94
Latin America	10 070	10 580	63.7	65.0	100	105
Near East	9 200	10 450	62.3	69.3	89	102
Developing centrally planned economies						
Asia	8 440	9 070	54.7	60.4	86	92
Total developing countries	8 780	9 200	54.9	57.4	91	95
World total	9 950	10 370	65.2	69.0	100	104

The availability of food throughout the world is uneven and in the developing world many people have a daily energy supply well below the recommended minimum (Table 21).

Table 21. The percentage of populations whose energy supply is below FAO recommended daily minimum.


Population in millions
500 0 500 1000 1500 2000 2500 3000
No. + % below limit
16% 462 2830 World
23% 434 1760 Developing regions
3% 28 1070 Developed regions
30% 301 1020 Far East
13% 36 280 Latin America
25% 67 280 Africa
18% 30 170 Near East

Food and Agriculture in the Future

The development target for agriculture was set at an increase in production of 4%/year by the United Nations for the decade 1970-79. Production in the world as a whole increased in the first four years by 2.1% in the developed world but only 1.9% in developing countries. The developing countries reached the 4% target only in 1975, but this still left the world average for the decade at 2.5%. The main international agency concerned with developing world agriculture is the Food and Agriculture Organisation of the United Nations. It is this agency that has been largely instrumental in promoting the so-called 'green revolution', which started in the mid-nineteen-sixties. Work at a number of international centres has led to the development of much improved strains of cereal crops, and these improved crops have had a significant impact on levels of world food production. The following centres have important roles to play in future agricultural development :

1. The International Rice Research Institute (IRRI), Los Banos, Philippines, one of the two oldest international centres and the one which served as a prototype for those that followed.

2. The International Maize and Wheat Improvement Centre (CIMMYT), El Batan, Mexico, whose success in developing new strains of wheat and high-lysine maize has already had a dramatic impact on developing country production (Fig. 22).

3. The International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, focusing on farming systems for the humid tropics, mostly in Africa, with special attention to the use of tropical soils.

4. The International Centre of Tropical Agriculture (CIAT), Palmira, Colombia, a pioneer in effective farming systems for lowland tropical areas of the Western Hemisphere.

5. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad, India, which stresses farming systems and water conservation methods of particular benefit to small-scale farmers in hot but water-short regions.

6. The International Potato Centre (CIP), Lima, Peru, a one-crop institute working to expand potato cultivation in developing areas.

7. The International Laboratory for Research on Animal Diseases (ILRAD), Nairobi, Kenya, one of the newest centres, currently concentrating on immunological methods for controlling two major animal diseases, East Coast fever and trypanosomiasis.

8. The International Livestock Centre for Africa (ILCA), located in Ethiopa, also new and working to increase animal production in the developing world through improved animal husbandry techniques.

It is to be noted that all the above centres and institutes are located in tropical countries. The emphasis on a vital transformation of agriculture in the tropics is necessary to bring relief to the masses, since population density is heaviest in the tropical regions of the world. The main objectives on the various programmes are: (i) to produce new varieties of crop plants and seeds that give higher yield; (ii) to improve the existing agronomic practices, including water resources, irrigation and fertilisers; (iii) to improve weed and pest control; (iv) to improve marketing arrangements, provide technical advice and storage facilities. More than 400 scientists are working in well-equipped laboratories with the necessary supporting staff.

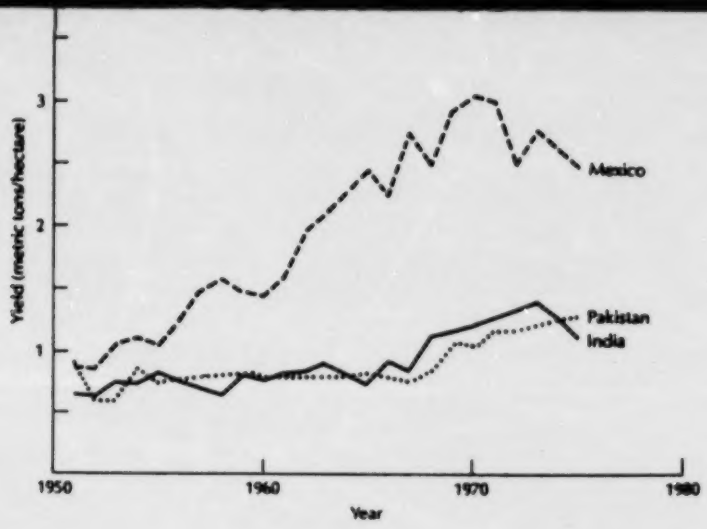


Table 22. High-yielding wheat varieties developed in Mexico resulted in a tripling of wheat production in that country. Introduction of these varieties into India and Pakistan also resulted in substantial gains. Decreased yields in India were due to the failure of the monsoon, but several years of good weather have resulted in increased wheat production.

Much of the increase in world food production has been brought about by recent advances in agriculture, which originated in the industrialised parts of the world. Many of these have been adapted subsequently for use in the developing countries. Some of these advances are :

1. The development of concentrated fertilisers.
2. The development of slow-acting fertilisers.
3. The development of micronutrient fertilisers.
4. The development of synthetic organic pesticides.
5. The development of synthetic herbicides.
6. The development of soil survey by aerial photography.
7. The development of the use of saline water in irrigation.
8. The extension of irrigation.
9. An increase in mechanisation.
10. The development of artificial insemination.

11. The development of the control of disease by vaccines.

12. The development of balanced livestock feeds.

13. The use of larger, more specialised fishing vessels.

14. The planting of fast-growing tree species.

15. The development of improved methods of food preservation.

16. Advances in plant product storage and pest control.

17. The development of new sources of protein.

18 The development of better assessment of human nutritional needs.

19. The use of atomic radiation in plant breeding, pest control and food preservation.

20. The use of computers for the coordination of agricultural programmes.

21. The development of the use of satellites to determine land usage.

Some of these advances have led to new problems, e.g. the build up of pesticides and herbicides in food chains, excess nitrogen in run-off water, etc. The development of biological control methods has helped but sometimes short-term gain has been sought in agricultural practice at the expense of longer-term conservation of resources. (A fuller discussion of these aspects will be found in the companion volume to this, "Ecology, Ecosystem Management and Biology Teaching".)

The problems of agriculture cannot be isolated from the whole social and economic context of a country. It is no use producing foods that people will not eat, whether because of customs or because the economic conditions are such that they cannot buy the food. Neither must we forget that natural hazards will continue and that food production in some years may be very low, so that methods of storage and transportation need to be made more efficient. It would not be wise either to expect to be able to introduce complete new systems into developing countries, without building up the necessary support facilities beforehand, e.g. new skills, advisers, veterinary services, specialised feedstuffs, transport, packaging and storage facilities. Development programmes need careful coordinated planning, so that agriculture is seen to be part of a social and economic structure which is capable of making progress as a whole. Many of the problems of food production will have to be resolved by individual developing countries, but this will be more successful if the developed and developing countries can work together.

Agriculture and Education

Agriculture is a very important applied area of biology. Scientific agriculture presently holds the key to the resolution of many problems in developing countries and will continue to do so for many decades to come. In any scheme of general education, the place of agricultural principles, processes and technologies should not be underestimated. This is true both for the rural poor and the urban elite and for developed as well as developing countries. The problems of food, energy and environment are of very great importance to mankind to-day; agriculture plays the central role in these problems and should be considered with high priority in any functionally-oriented biological education.

The United Nations set a development target of 4% for the decade 1970-79 (see Chapter 5, p.46). The results have been disappointing. Similarly, the hopes associated with the use of new high-yielding varieties of crops in developing countries - the so-called Green Revolution - have not been fully realised. One can point to a variety of reasons for this. In all cases, among the reasons for a lack of success have been constraints, such as available technology, economic feasibility and communications means. The provision of agricultural machinery to a developing community is unhelpful if spare parts and maintenance facilities are unavailable. The provision of new high-yielding crop seed was only successful where the farmers understood that more optimal conditions of growth were required by the new varieties than the local varieties, their farms were large enough, equipped with appropriate machinery and supplied with adequate fertilisers and pesticides. Clearly, biological knowledge is relevant to the resolution of many issues facing developed and developing countries, and this is particularly true of problems of agriculture. However, the application of biological knowledge to the resolution of problems involves a number of factors, as instanced above. Blum (1982), in discussing the question of the relevance of biological knowledge to community development, suggests a model to show how such knowledge can be applied to community issues (Fig. 11).

Biology teachers, in attempting to include aspects of agriculture in their biology teaching, may find such a model useful in helping to see the context in which the biology they teach relates to practical problems. Through their own training, biology teachers will have an understanding of the principles which underly agricultural practices and processes, although they may be unfamiliar with these practices, and more particularly the economic, social and technical constraints within which any agriculture operates.

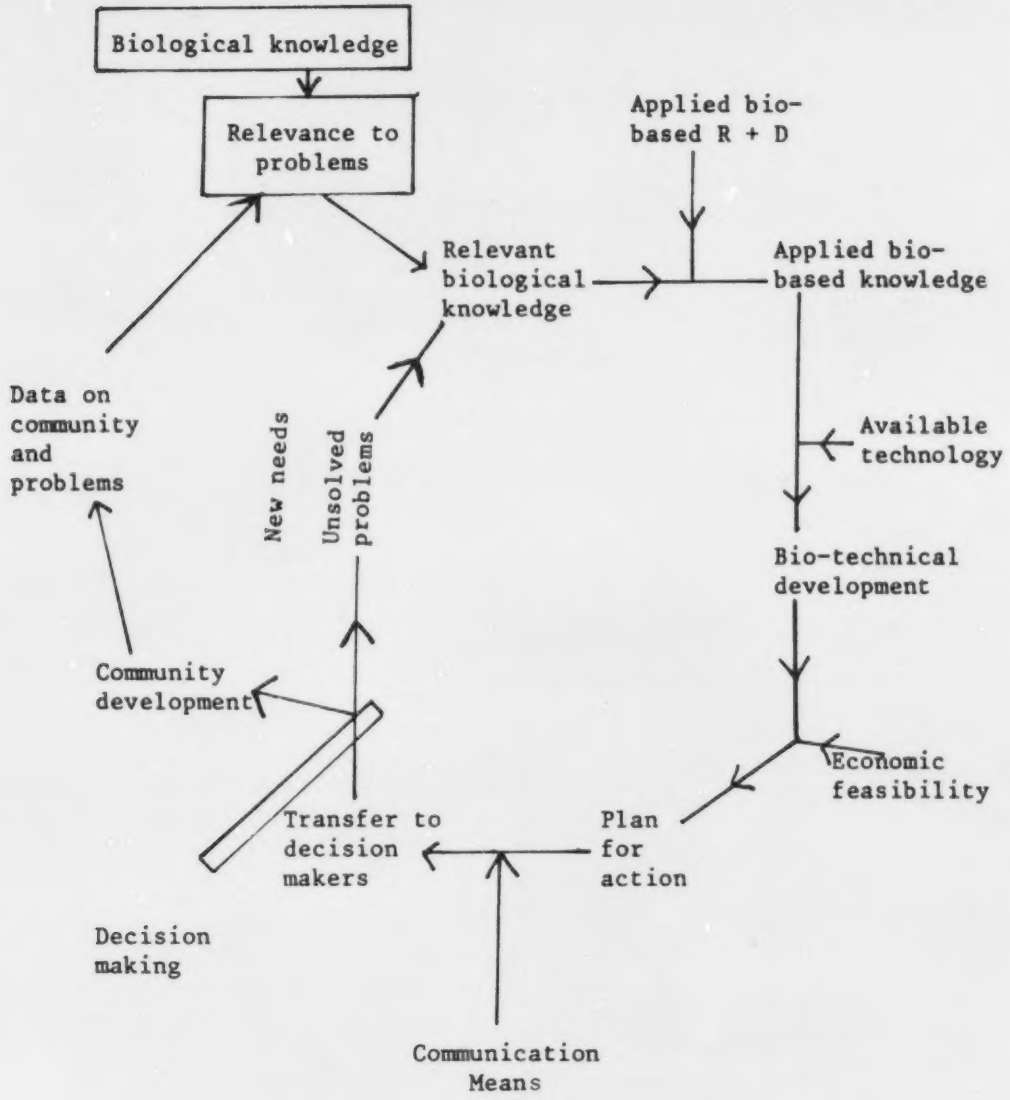


Fig. 11. Biological knowledge to Community Development Cycle (Blum, 1982).

Any attempt for biological education to contribute to combatting problems of agriculture will involve (a) structural questions for the biology curriculum itself and its relationship to other parts of the school curriculum, and (b) the development of a wider range of teaching and learning strategies than biology teachers commonly use at present.

Curriculum Issues

A biology programme will be concerned with the factors which affect the long-term well-being of the land and of plants and animals. An agricultural dimension would involve also developing an understanding of man's utilisation of the Earth's resources, and the science and technology applied to the production of food and other biological resources.

Biology exists in school curricula in a number of forms, principally as a separate subject in its own right, but also as a component of general or integrated science and, perhaps less frequently, in the form of environmental science, rural science and even agricultural science (the latter being usually vocational rather than general education in aim).

Biology programmes in many parts of the world have, in recent years, attempted to include more explicit references to agriculture, with elements such as crops, their diseases and pests; animal husbandry; irrigation and soil conservation. However, besides the explicit coverage of such areas, much of the biology traditionally taught involves principles which find application in agriculture. An Asian regional workshop was organised in the Philippines by UNESCO in 1980. The workshop was concerned to review biology education at the secondary level. One focus was on health, nutrition and education. This review attempted to identify the areas of traditional biology with applications in, among other things, agriculture, from a synthesis of various Asian countries' experiences. Table 23 illustrates their results.

Such considerations can similarly be applied to programmes of integral science, with not only an explanation of the applications of biology in agriculture, but those of the other sciences too. A UNESCO study on Agriculture and Education (Unesco, 1971) puts the view that (a) pure science teaching has tended to neglect any understanding of the significance of natural resources, and (b) laboratory work alone minimises the three most important components of a field scientist's repertoire - the need to determine relevance amongst the multitude of possible observations, the knowledge of where to go for accurate technical advice, and the ability to solve problems on the spot. However, it goes on to say that it is still essential that pupils in secondary schools should have the opportunity to learn the sciences and that it should not be the intention to replace science with agriculture, rather that links should be built up so that the applications of science can be more readily understood. In developing this idea, the following set of examples in reference to a functional biology syllabus was put forward for consideration.

1. The living plant as a factory; uptake of water and salts (rainfall and crop production, irrigation fertilisers).

2. Carbon assimilation and nitrogen assimilation (starch and sugar producing crops, the nitrogen cycle, the value of legumes for human nutrition and soil improvement).

Table 23. Agricultural Aspects of Biology Education

Area of concern	Concepts / Principles / Topics	Practical experiences for students	Teaching / Learning strategies	Developing values / Intellectual skills	Levels Lower	Levels Higher
Agriculture						
a) Factors affecting crop production	– Biotic factors and interaction – Concepts of limiting factors – Concepts of tolerance – Carrying capacity	– Case studies – Field work – Designing remedial experiments – Identification of visual symptoms of limiting factors	– Project work – Games – Lecture – Discussion	– Awareness of conservation of soil and water resources – Appreciating the need for proper management of soil and water resources – Awareness of production limits of ecosystems	✓	✓
b) Varietal improvement c) Use of non-conventional food sources	– Breeding – Asexual reproduction – Mutation – Genetic conservation – Introduction of new species	– Field trip – Performing asexual propagation methods – Setting up school nurseries – Actual breeding experiment in plants and animals	– Lecture – Discussion – Audio-visual aids – Case studies	– Skills in analysis of pedigree – Skills in breeding asexual propagation of plants – Awareness of new role of heredity in development of organisms – Awareness of negative and positive effects of breeding	✓ ✓	✓ ✓
d) Pest and diseases control	– Biotic relationship – predator prey – host specificity – competition – allelochemics – Development of resistance to biocides (pesticides, weedicides, herbicides)	– Field work – Case study – Experiments – Familiarity with biocides (pesticides, weedicides, herbicides) and their uses – Collection – Preservation of specimens	– Decision-making – Games – Lecture – Discussion – Audio-visual – Use of biological specimens – Use of resource persons including farmers	– Awareness of important biotic relationship – Develop attitude for conservation and maintenance and proper biotic relationship – Skill for developing proper agricultural practices for pest and disease control and management (intercropping, multiple cropping, biological control)	✓	✓

Table 23 continued

Agricultural Aspects of Biology Education (cont'd)

Area of concern	Concepts / Principles / Topics	Practical experiences for students	Teaching / Learning strategies	Developing values / Intellectual skills	Levels: Lower	Levels: Higher
e) Pollution (including biocides and agricultural waste management)	– Food chain relationship – Hydrologic cycle – Material cycling	– Case studies – Monitoring studies using ecological indicators – Field collection/preservation – Identification of ecological indicators – Collection and separation of biodegradable/non-biodegradable farm waste materials		– Develop proper attitudes towards the use of pesticides, weedicides and fertilizers – Appreciate value of farm waste as a source of energy and fertilizer – Develop proper methods of agriculture waste disposal	✓	✓
f) Integrated farming systems for efficient resource utilization and management	– Energy flow and material cycling – Ecological efficiencies – Homeostasis and steady state	– Case studies – Field work – School projects on recycling	– Audio-visual i.e., charts, slides – Lecture – Discussion	– Appreciate the value of diversified production system		✓
		– Practical experiences in the farm	– Need resource assessment	– Appreciate the value of farm waste as alternative source of energy and fertilizer – Develop proper management strategies for integrated farming		

3. Respiration and combustion (rôle of air in the soil, importance of silage for germination and root aspiration).

4. Insects (insects as friends of the farmer, pollution, decay of organic matter, insects as pests and their control - chemical, biological, mechanical, ecological; life-cycle of insects, insects and storage).

5. Fish (importance for human consumption, fish-farming, fresh-water ponds).

6. Soil (more emphasis on organic matter and organic life than normally offered in biology courses).

The biology approached from an ecological angle and based on possibilities provided by the school environment, e.g. the relationship of one particular local crop and an insect, or the effect of a given weed. Detailed studies based on local agricultural problems, e.g. the nutrition deficiencies of a local crop, the life-cycle behaviour pattern and natural enemies of a particular insect, would emphasise applied biology and its role in agricultural research.

In considering the application of biology to everyday life, and in particular to a concern for agriculture, rural studies presents an interesting approach to science education in general and biological education in particular. There are persuasive arguments for a greater development of specific rural science programmes, especially in those countries of the world which have a large proportion of their population engaged in agriculture. Blum has argued that rural studies are not only of relevance to the less able but can excite the interest of very able students (Blum, 1976). In well-developed rural science courses, scientific concepts arise from the basic investigatory value of the subject and a holistic approach. Scientific principles can, in such courses, be applied to the solving of immediately perceived and identifiable problems arising from the pupils' own observations of a practical situation, which is generally initiated by their experience with the plants and animals, or land, for which they are responsible. At the heart of such courses lies the children's work on an agricultural or horticultural holding. It is as a result of this that the pupils are more involved in a personalised view of science than that arising from more traditional science courses. This may be at an emotional level, such as when seeing and assisting in the birth of an animal, or in making value judgements about the welfare of animals and conservation issues at first hand. There is every reason to believe that a rural science approach to science education could be of great benefit in many parts of the world. If a rural science programme is envisaged, then appropriate resources are required. Since the essence of rural science lies in the application of biological and other scientific principles, so it follows that opportunities to exercise these applications need to be available. Certain basic facilities need to be provided, in

particular - appropriate laboratory space, a tool store and work area, animal housing, a plot of ground and a simple weather station.

Patterns of study in rural science programmes need to use as starting points children's direct experiences, and to maintain this as a constant feature of the work. The programme structures are derived from agricultural or horticultural topics and draw upon biological - and other - principles, rather than organised on a biological structure. A farm may be the children's direct experience. The aim in the long term would be to help the children to come to an understanding of a farm as an ecological unit whose balance is dependent on human intervention. The elements of this part of a programme are illustrated (Fig. 24).

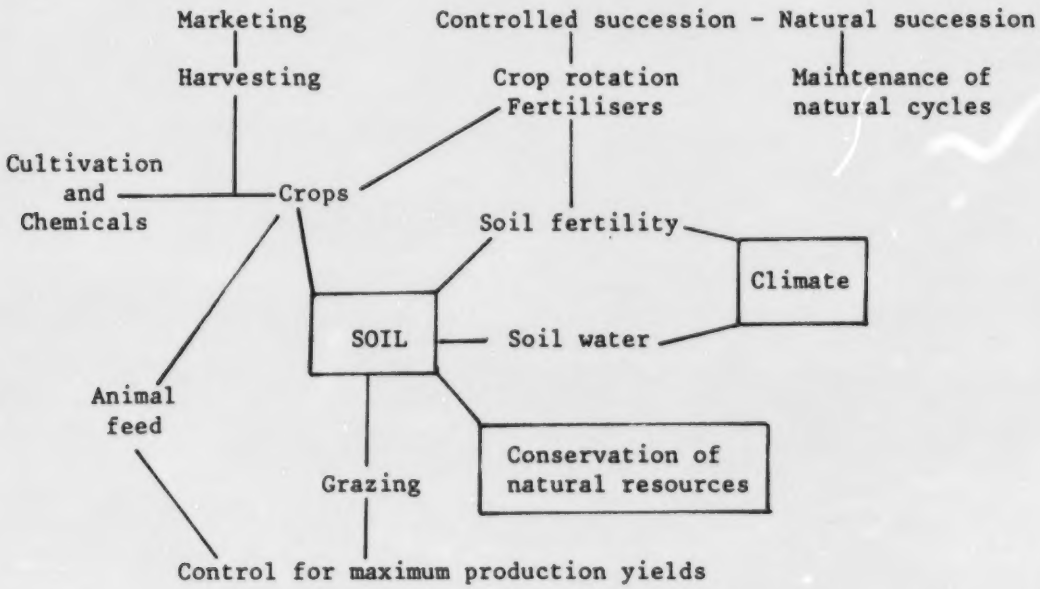


Fig. 24. A farm as an ecological unit.

This figure identifies what children can experience directly through rural science, and each area of experience will have particular biological (as well as other scientific and geographical) knowledge relevant to it.

A rural science approach can be incorporated into conventional school programmes, either where they become relevant, or by means of discrete modules of rural science, or as part of a common core science curriculum, or as an integrated study linking a number of traditional subject areas.

Biology teachers wishing to develop an agricultural dimension to their programmes in whatever form will find it helpful to liaise closely with teachers of geography, the other sciences and craft and technology.

Teaching and Learning Strategies

The aims and styles of teaching biology have changed significantly over the past decades. Biology teachers to-day employ a wide variety of teaching/learning strategies, ranging from those concerned with a scientific/descriptive approach to those embracing a concern for social relevance and moral values. Kelly has described these different approaches respectively as Knowledge Studies and Issues Studies (Kelly & Schaefer, 1980). Knowledge Studies involve inquiry learning, among other things, and Issues Studies involve an exploration of attitudes and values. Meyer, in surveying biology education, suggests that most school systems have reached at least the stage of inquiry learning and many are also incorporating an issues studies approach (Meyer, 1982). The inclusion of an agricultural dimension into biology programmes must involve both Knowledge and Issues Studies approaches, e.g. selective weedkiller as a topic can be dealt with in an inquiry mode, using experiments designed to investigate plant hormones, and further experiments on the effectiveness of particular herbicides (Knowledge Studies); equally, issues of social concern can be discussed, such as the broader ecological significance of the widespread use of such substances (Issues Studies).

If we include aspects of agriculture in biology programmes, because we see this as a means of making biological education more likely to serve community needs, then we need through this to encourage pupils to seek biological knowledge in order to solve practical problems. This will involve a very careful mixture of knowledge and issues studies approaches. It may be helpful to see this mixture in terms of an Applied Studies approach in which the selected teaching and learning strategies have two important elements: (a) problems identified by children arising out of practical agricultural or horticultural situations; and (b) involve children in making decisions about alternative practices. The development of an applied studies approach in biology presents teachers not only with new subject matter but may also involve new teaching techniques.

The development of forms of work concerned to encourage pupils to apply biological knowledge to the resolution of practical problems will incorporate a variety of methods of teaching and learning. Such work could be based on the development of a school's own plot of land, or through the school being associated with a local agricultural holding. The development of an 'agricultural trail' would be a useful resource for initiating and developing work, together with the collection by the school of data associated with the trail - data such as soil properties, rainfall, cropping yields, etc. Such local data could be supplemented by information

available from regional, national and world sources. These resources would be a useful basis for developing field and laboratory investigations, theoretical exercises, role play debates, and simulation exercises, together with audio-visual materials. Skilful sequencing of these various activities related to pupils' interests and abilities is an important ingredient in successful applied studies in biology. Equally, very careful selection and presentation of reading material and scientific data is necessary in such work.

Examples of these different types of work might be :

(a) Laboratory and Field Investigations

An investigation of the use of fertilisers.

(i) Field investigation - fertilised and unfertilised plots;

(ii) A laboratory investigation - growing the same crop plants in solutions deficient in certain substances.

(b) A Theoretical Exercise

Reproduction and Productivity in Pigs - a worksheet giving :

(i) farm records of a breeding sow (e.g. when mated, number of litter and dates of birth, number of litter which survive, etc.), followed by questions on the breeding quality of the sow;

(ii) farm records on pig foods and growth rates of pigs, e.g. the percentage fat, protein, carbohydrate and fibre content of pig food; mass of pig at weaning, mass of pig at slaughter, mass of pig food eaten during lifetime;
followed by questions such as how much protein does the pig consume in its lifetime?; how much fat?; how much carbohydrate?;
leading to questions on the energy and food quality efficiency of pig production.

(For a full worksheet example see Nuffield Secondary Science *Teacher's Guides 1-8*, London 1971).

(c) Simulation Exercises

An interesting example of some teaching/learning strategies and materials is in the 'Ridpest File' developed at Bath University (United Kingdom). The File consists of four decision-making exercises on the subjects of pests and their control. The necessary data is presented in the form of a filmstrip, tape-recording and an information bank, consisting of sets of cards. The cards contain all the information which the students need to solve the problems posed. Worksheets have been designed

to introduce the student to the pest under discussion, the particular problem to be solved and the tasks to be undertaken in order to come to a decision. The essence of these exercises is to introduce pupils to decision making situations in agriculture.

(The Ridpest File, Wells, J. & Crisp, S.J. Bath University School of Education/British Agrochemicals Association (1976)).

It would not be difficult to develop similar exercises in relation to the sort of decision-making situations which farmers face in different regions of the world.

(d) Role-Playing Debates

The Farming Game - participants play the part of farmers in their own region, tradespeople, housewives, etc., reflecting different, and sometimes conflicting, interests. Each group, with the help of the teacher, obtains information relevant to their role in relation to the issue under consideration, and which they use in the debate. The issue may be, for example, the local water supply and the various effects farmers' practices have on this. Such activities can help pupils to see the value of biological knowledge to a consideration of issues, and also the need for recognising different forms of judgement about an issue.

There is further consideration of teaching/learning strategies and curriculum issues, relevant to many issues raised in this volume, together with useful bibliographies, in the companion volumes to this one: Ecosystem Management, Health, and Biological Systems as Energy Resources.

Teaching Resources

Useful materials for teachers are often available in the publications of Ministries of Agriculture. Two international agencies, which produce information and teaching aids, are :

The International Tea Promotion Association,
P.O. Box 30007 3011 AE, Rotterdam, The Netherlands.

The London Coffee Information Centre (Coordinator of Educational Policy), 21 Berners Street, London W1P 4DD, United Kingdom).

The publications of the Food and Agriculture Organisation contain much information relevant for biology teachers. There are many other agencies which produce material specifically for educational use, such as the Centre for World Development Education (128 Buckingham Palace Road, London, UK) (although much of this material is aimed at UK students, it could be usefully used in developing countries also). Charitable agencies also produce useful educational material on food and agriculture, e.g. Oxfam, War on Want, Save the Children Fund and the Catholic Fund for Overseas Development.

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The aim of this list is to direct the reader to references used in the text and also to sources that are rich in further references, so that bibliographies, resources and curriculum materials appropriate to the reader's own geographical location may be identified. The bibliography and resource list in the companion volume, Ecology, Ecosystem Management and Biology Teaching, has relevant material also, and references identified there have not been duplicated in this list.

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